Manual reloj

REAL-TIME GPS

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1. Introducción

1.1 GPS

El Sistema de Posicionamiento Global (Global Positioning System), se basa en una red de 24 satélites en órbita alrededor de la TIERRA lanzados por el Departamento de Defensa de los EEUU con fines militares, además de los usos militares han surgido aplicaciones para usos pacíficos, como los sistemas de navegación, referencias de tiempo, etc.

El Sistema GPS se basa en la medida de distancias desde un punto a un numero de satélites, es decir que aplicando cálculos matemáticos de triangulación podemos conocer nuestra posición con alta precisión. Desde cualquier parte de la superficie terrestre siempre se tiene visión (si no lo impiden obstáculos) de al menos 4 satélites, que es el número imprescindible para conocer nuestra posición con total exactitud (latitud, longitud y altitud).

¿Cómo se obtiene la distancia a los satélites? Bien, en cada satélite del sistema GPS viaja un reloj atómico sincronizado con otro que está en la Tierra, es decir todos cuentan con un patrón de tiempo UTC (Tiempo Universal Coordinado). Un receptor GPS situado en la superficie de la Tierra, puede calcular en función de lo que tardan las señales enviadas por los satélites hasta el receptor, la distancia a ellos y por consiguiente la posición.

1.2 El reloj, sincronización GPS

Uno de los usos pacíficos de esta tecnología es la posibilidad de disponer de un patrón de tiempo UTC en cualquier parte de la Tierra.

Como ya hemos comentado, los satélites incorporan un reloj atómico sincronizado con una estación base, para que los receptores GPS puedan calcular las distancias a los satélites es necesario que estos estén sincronizados con los relojes de los satélites, aprovechando esta circunstancia se ha desarrollado el equipo que nos ocupa: “REAL-TIME GPS V02”.

El “REAL-TIME GPS V02” es un reloj basado en GPS que incorpora un receptor GPS “Resolution T” (TRIMBLE) de alta precisión. Ha sido desarrollado para atender la demanda de las empresas del Sector Eléctrico de Transporte como estación de sincronización en Subestaciones Eléctricas.

Las Subestaciones Eléctricas cuentan con equipos electrónicos que monitorizan y protegen la Red, cuando se produce una perturbación en esta Red normalmente afecta a varias subestaciones por lo que una referencia de tiempo común en cada subestación es de gran utilizad a la hora de analizar dichas perturbaciones o incidentes.

El “REAL-TIME GPS V02” implementa los protocolos de sincronización más usados por los equipos de monitorización y protección empleados por las empresas del sector. Entre los protocolos disponibles están:

REE: utilizado por los equipos de control.

IRIGB003/4: utilizado por la mayoría de las protecciones.

IRIGB123/4: utilizado por algunas protecciones.

PPS: utilizado por algunos registradores de incidentes.

Además, el reloj cuenta con un display LCD en donde es posible ver la información horaria, el estado del reloj, el número de satélites adquiridos, etc. Dispone también de unos LED que señalizan otros aspectos de su funcionamiento.

2. Descripción

2.1 Características

Como ya hemos mencionado, el REAL-TIME GPS V02 dispone de un receptor GPS "Resolution T" que es el encargado de recibir las señales de los satélites y proporcionar una referencia de tiempo de alta precisión, según hoja de características el Resolution T proporciona una señal PPS con un error de +/- 15 nanosegundos. Partiendo de la señal de PPS se generan todos los protocolos de sincronización que proporciona el reloj, las referencias de tiempo de estos protocolos se generan por hardware con la señal PPS, con lo que los errores o retrasos se reducen a los tiempos de transición de la electrónica (pocos nanosegundos).

La generación de los protocolos y demás procesos internos del reloj quedan en manos de un microcontrolador ATMEGA128 de ATMEL que cuenta con dos UART, una para atender los mensajes del receptor GPS y otra para proporcionar el protocolo REE.

El REAL-TIME GPS V02 se suministra en una caja para rack de 19" x 1U, todos los conectores correspondientes a los interfaces están disponibles en la parte trasera, incluyendo el conector de antena y de alimentación.

ALIMENTACION

La entrada de alimentación se realiza mediante un conector con filtro EMI integrado, que está situado en la parte trasera del equipo y señalizado como (POWER).

El reloj dispone de una fuente de alimentación aislada, con rangos de entrada según opción, 48 VCC (36 a 72 Vcc), 125 Vcc (90 a 300 Vcc) y 220 Vac (85 a 264V), con una potencia de 10W y 82% de eficiencia.

La salida proporcionada por la fuente es de 5 Vcc y 2 Amp.

RELE AL

El reloj cuenta con un relé de señalización que nos indica si el reloj está en correcto funcionamiento o bien presenta algún problema hardware o software.

La salida de este relé se realiza mediante un conector enchufable de tres vías (A(na), M(común), C(nc)) que esta señalizado como (RELE AL).

IRIGB

El REAL-TIME GPS V02 genera el protocolo IRIGB en dos formatos: IRIGB003, IRIGB004, IRIGB123 y IRIGB124.

El IRIGB003/4 está presente con los siguientes interfaces:

- TTL, mediante conector BNC con impedancia de salida de 50 ohm.
- FO, mediante una señal óptica de 820 nm de longitud de onda con conector ST, para fibras multimodo 50/125 µm, 62.5/125 µm y 100/140 µm.
- RS485, mediante un conector enchufable de tres vías (A, B y T). La salida está protegida contra sobretensiones mediante diodos supresores de transitorios y fusibles rearmables, además el driver RS485 está aislado galvánicamente del resto de la electrónica mediante un optoacoplador rápido y un convertidor DC/DC.

El IRIGB123/4 está presente mediante un conector BNC con impedancia de salida de 50 ohm. De esta salida se obtiene una señal analógica senoidal de 1KHz, modulada en amplitud que cumple las especificaciones relativas a IRIGB modulado. La modulación de la señal se realiza con el protocolo IRIGB003/4.

PPS

El reloj proporciona una señal de referencia denominada Pulso Por Segundo (PPS), generada directamente por el receptor GPS, está presente en dos formatos:

- TTL, mediante conector BNC con impedancia de salida de 50 ohm.
- FO, mediante una señal óptica de 820 nm de longitud de onda con conector ST, para fibras multimodo 50/125 µm, 62.5/125 µm y 100/140 µm.

1KHz

Además del PPS el reloj también proporciona una señal cuadrada sincronizada con el PPS, de 1 KHz, en formato:

- TTL, mediante conector BNC con impedancia de salida de 50 ohm.

Pulsos Programables

El REAL-TIME GPS V02 es capaz de generar trenes de pulsos, configurables en anchura, frecuencia, número de pulsos, polaridad y periodo de repetición. Estos pulsos están disponibles en dos formatos:

- TTL, mediante conector BNC con impedancia de salida de 50 ohm.
- FO, mediante una señal óptica de 820 nm de longitud de onda con conector ST, para fibras multimodo 50/125 µm, 62.5/125 µm y 100/140 µm.

Protocolo REE

Otro de los protocolos proporcionado por el REAL-TIME GPS V02 es el REE, se trata de un protocolo serie ASCII que contiene la información de fecha, la hora y ciertos caracteres de control. Este protocolo está disponible en los siguientes formatos:

- FO, mediante una señal óptica de 820 nm de longitud de onda con conector ST, para fibras multimodo 50/125 µm, 62.5/125 µm y 100/140 µm.
- RS485, mediante un conector enchufable de tres vías (A, B y T). La salida está protegida contra sobretensiones mediante diodos supresores de transitorios y fusibles rearmables, además el driver RS485 está aislado galvánicamente del resto de la electrónica mediante un optoacoplador rápido y un convertidor DC/DC.

- RS232, mediante dos conectores Sub-D Hembra de 9 pines, señalizados como (REE1 y REE2). Se utilizan los pines 2, 3 y 5 del conector, para la selección del pin por el que salen datos hay un jumper por cada salida, JP6 para REE1 y JP8 para REE2, que están configurado por defecto en posición (2-3) es decir TX por el pin 3, los parámetros relativos a su configuración están fijados por el propio protocolo (9600 bps, 7 bits de datos, 1 bit de stop y paridad par). Estas salidas están protegidas contra sobretensiones mediante unos diodos supresores de transitorios y además el driver RS232 está aislado galvánicamente del resto de la electrónica mediante un optoacoplador rápido y un convertidor DC/DC.

Entrada de antena

La señal enviada por los satélites es recibida por una antena que se conecta en la parte trasera del reloj mediante un conector BNC, la impedancia de entrada es de 75 ohm.

Una vez descritos los elementos que podemos encontrar en la parte trasera del reloj, pasamos a describir los elementos presentes en el frontal:

Interruptor de alimentación

Es el elemento encargado de encender y apagar el reloj

DISPLAY LCD

Se trata de un Display LCD de 20 caracteres por dos filas, que cuenta con retroiluminación para facilitar la visualización de la información que se presenta incluso en condiciones de baja iluminación ambiental.

En este display podemos ver:

```
VIE 25-07-2003 J:206
```

VIE Día de la semana en formato “ddd” siendo Lun, Mar, Mié, Jue, Vie, Sab, Dom

25-07-2003 Fecha en formato “dd/mm/aaaa”

J:206 Día Juliano en formato “XXX”

13:27:00 Hora en formato “hh:mm:ss”

+02 Diferencia horaria con respecto a UTC en formato “+/-XX”

W En la posición de este carácter pueden aparecer los mismos caracteres que en el protocolo REE (ver apartado 3.1 REE).

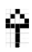
- Indica error en precisión

* - Indica fallo hardware o software.

 - Si coinciden en el tiempo los dos fallos anteriores

“ “ - Indica funcionamiento correcto sin errores.

X En la posición de este carácter puede aparecer:

 - Indicando que la antena está conectada y no hay problemas.

 - Consumo de la antena fuera de margen.

 - Tensión en antena fuera de margen.

 - Tensión de la batería baja.

- Error de comunicaciones con el receptor GPS.

- Cuando coinciden en el tiempo dos o más de los fallos anteriores.

Y En la posición de este carácter puede aparecer:

“S” - Indicando que estamos en modo SIMULACION.

“P” - Indicando que hay PULSOS PROGRAMADOS.

“ “ - Indicando que no existen ninguna de las circunstancias anteriores.

Z En la posición de este carácter puede aparecer:

“G” - Indicando que la hora y la fecha se obtienen de GPS.

“R” - Indicando que la hora y la fecha se obtiene del reloj interno RTC.

04 Número de satélites utilizados en ese momento por el GPS en formato “XX”

Una situación de funcionamiento optimo presentaría un aspecto como este:

```
VIE 25-07-2003 J:206
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LEDS de señalización

El equipo dispone de un total de 8 LED (3 verdes, 1 bicolor y 4 rojos) con los que se proporciona la siguiente información:

LED POWER	Verde. Indica que el equipo dispone de alimentación.
LED RUN	Verde. Indica que el reloj está en funcionamiento optimo sincronizado con GPS.
LED ANT	Verde. Indica que la antena está conectada y su consumo está dentro de margen.
LED GPS	Bicolor. Verde. Indica que el receptor GPS está enviando datos al micro. Rojo. Indica que el micro está enviando datos al receptor GPS
LED REE	Rojo. El reloj está generando y enviando el protocolo REE
LED PPS	Rojo. Indica la actividad del PPS
LED IRIGB	Rojo. El reloj está generando y enviando el protocolo IRIGB
LED PP	Rojo. Indica la actividad de los Pulsos Programados.

2.2 Operación

El REAL-TIME GPS V02 tiene dos modos de operación:

MODO RELOJ

Es el modo de funcionamiento normal, se llega a este modo una vez que hemos encendido el equipo. Las funciones que realiza el reloj en este modo son:

- El receptor GPS recibe los mensajes de lo satélites para calcular su posición y generar el PPS.
- El receptor envía al microcontrolador mensajes en protocolo TSIP (Trimble Standard Interface Protocol).
- Se generan los mensajes de sincronización REE y IRIGB
- Se comprueba si existen pulsos programados y se actúa en consecuencia
- Se chequea los parámetros de funcionamiento.
- Se refresca la información del display LCD

MODO MONITOR

En modo Monitor es posible cambiar un amplio número de parámetros de configuración del equipo, se accede a este modo a través del conector frontal “MONITOR”. La configuración de este puerto está fijada a 9600 bps, 8 bit de datos, 1 bit de stop y sin paridad.

Para entrar en modo “MONITOR” es necesario un programa emulador de terminal como el HyperTerminal , una vez que hayamos configurado el puerto serie de nuestro ordenador nos conectaremos al conector indicado y pulsaremos la tecla “ESC”, el reloj nos pedirá que introduzcamos la PASSWORD para acceder a los menús y al cambio de idioma.

De fabrica el equipo sale con la PASWORD por defecto a “1234”.

Desde el modo MONITOR podremos:

- Configurar el receptor GPS
- Configurar la funcionalidad del reloj.
- Configurar los pulsos programables.
- Entrar en modo simulación
- Cambiar de idioma (español, inglés, otros).
- Volver a MODO RELOJ

Las limitaciones de este modo son:

- No se generan mensajes de sincronización.
- Se pierde la sincronización GPS
- El display solo informa del estado de funcionamiento actual.

El MODO MONITOR es un estado temporal del que se sale automáticamente pasados 180 segundos de inactividad. La salida a MODO RELOJ ya sea manual o automática equivale a un RESET caliente de la unidad.

3. Protocolos

3.1 REE

El protocolo de tiempo REE, es un protocolo ASCII transmitido por vía serie; responde a las especificaciones de la empresa Red Eléctrica de España S.A. que lo desarrollo o adapto para sincronizar sus equipos de control.

Como ya hemos mencionado es un protocolo ASCII cuya estructura es la siguiente:

StxD: dd:mm:aa; T:s; U:hh.mm.ss; #*S!Etx

Donde:

Stx = $02

D

:

Dd = Día del mes con dos dígitos

:

Mm = Mes con dos dígitos

:

'aa = Año últimos dos dígitos

;T:

s = Numero del día de la semana

;U:

Hh = Hora con dos dígitos

.

mm = Minutos con dos dígitos

.

Ss = Segundos con dos dígitos

;

= Error de precisión, indica que el reloj no está sincronizado con GPS sino con el reloj interno RTC.

* = Fallo hardware o software, es generado de la misma manera que se indicó en el apartado 2.1 Características (DIUSPLAY LCD).

S = Horario de verano, " " horario de invierno,

! = Aparece una hora antes del cambio de verano a invierno

Etx = $03 generado por hardware mediante el PPS

En total 32 caracteres.

El carácter ETX del protocolo valida el tiempo del mensaje, esto implica que en el mensaje se indica un segundo de adelanto con respecto al patrón de tiempo.

Para conseguir la máxima precisión, el reloj dispone de un generador hardware del carácter ETX, de tal manera que cuando se hace presente el flaco activo del PPS el carácter es generado automáticamente.

3.2 IRIGB

El protocolo de tiempo IRIGB es una de las variantes de las especificaciones IRIG, que atienden a los estándares 200-98, 200-04 desarrollados por varias agencias gubernamentales de los EEUU y la industria privada.

A modo de resumen diremos que los IRIGB generados por el reloj son:

- IRIGB003 y IRIGB123 (estándar 200-98)

- IRIGB004 y IRIGB124 (estándar 200-04)

El IRIGB004 cumple además con la IEEE C37.118, referente a calidad de sincronización en la medida de sincrofasores.

Son protocolos serie en donde la información viene codificada en BCD. Se genera una trama con información una vez por segundo, dentro de esta trama hay un punto que valida la hora del mensaje, pero en este caso está al comienzo de la trama, por lo que la hora codificada es la que corresponde a este punto.

Para garantizar la precisión, los datos son generados por el micro y cargados en un circuito hardware (FPGA), para que en el momento corresponde con el flanco activo del PPS este circuito genere la trama IRIGB.

El jitter es menor de 100 nanosegundos.

En el caso del IRIGB123/4, que es homologo al IRIGB003/4 en cuanto a la información codificada, es necesario disponer de un generador senoidal de 1KHz síncrono también con el PPS, esta señal senoidal es modulada en amplitud por la trama IRIGB003/4, de esta función se encarga también el mismo circuito hardware (FPGA).

Para más detalles del protocolo consultar el ANEXO I.

3.3 PPS

Realmente no es un protocolo, ya que no codifica ni transporta información alguna, simplemente es como su nombre indica un Pulso Por Segundo, pero es de suma importancia para el funcionamiento interno del REAL-TIME GPS V02, ya que todos los procesos y acciones internas son síncronos con el flanco activo de este pulso.

La precisión del reloj depende directamente de la precisión del PPS, de ahí la importancia de contar con un receptor GPS que garantice la precisión de esta señal, el REAL-TIME GPS V02 dispone de un receptor GPS Resolution T que genera el PPS con un error de +/- 15 nanosegundos.

El PPS es accesible externamente, ya que hay equipos en el mercado que requieren de esta señal para poder funcionar adecuadamente (registradores de incidencias basados en la mediada de fasores en tiempo real).

El PPS tiene una anchura de 1 mseg.

4. Pulsos programables y simulación

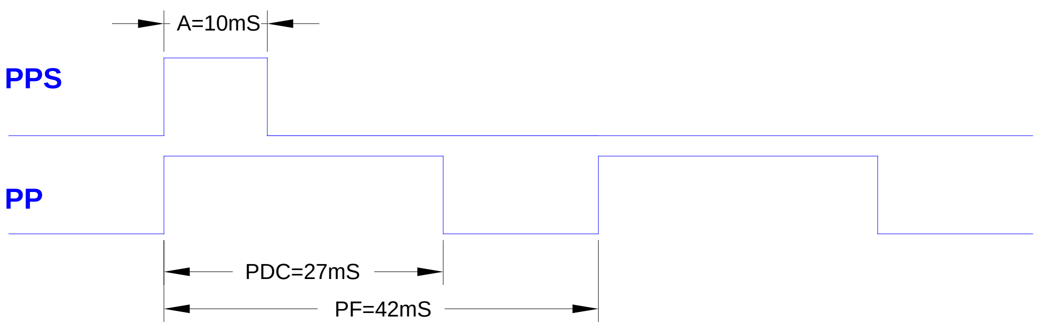
4.1 Pulsos programables

El REAL-TIME GPS V02 dispone de un generador de pulsos programable síncrono con el flanco activo del PPS.

Desde el MODO MONITOR es posible programar este generador que destaca por:

- Generación de pulsos con periodo comprendido entre 1 mSeg a 999 mSeg (PF).
- Posibilidad de ajustar el Duty-Cicle o relación entre el 0 lógico y el 1 lógico (PDC).
- Posibilidad de seleccionar la polaridad de los pulsos.
- Posibilidad de generar trenes continuos o por número de pulsos.
- Posibilidad de repetición en el tiempo con saltos desde 1 segundo hasta años.

La salida de este generador es eléctrica (BNC) y óptica (FO multimodo).



4.2 Simulación

Con el REAL-TIME GPS V02 es posible hacer simulación de tiempo, esto quiere decir que podemos colocar el reloj y el calendario en una hora y fecha determinada para probar algún cambio horario o saber en qué día de la semana cayo o caerá una determinada fecha.

El acceso a esta función se realiza desde el MODO MONITOR.

En modo SIMULACION el protocolo REE y el IRIGB se generan correctamente acorde con la simulación. Para garantizar la precisión de la simulación, esta será síncrona con el PPS.

El estado simulado se indicará en el DISPLAY con la letra "S".

5. Instalación

5.1 Lista de materiales

El REAL-TIME GPS V02 se suministra en un embalaje que contiene:

1.- Una unidad REAL-TIME GPS V02.

2.- Cuatro tornillos y tuercas de fijación para mecánica de 19".

3.- Un conector hembra de tipo Red.

Dado que el receptor GPS es compatible con un gran número de antenas activas (75 ohm de impedancia) del mercado, está no es suministrada junto con el equipo, aunque si se desea podrá ser adquirida como un accesorio.

5.2 Ubicación

La ubicación de la antena es fundamental para un correcto cálculo de la posición y por lo tanto del tiempo, es necesario elegir un lugar libre de obstáculos que impidan tener una visión directa del cielo, ya que las señales enviadas por los satélites se transmiten en línea recta.

La mejor ubicación es aquella en la que desde el punto de colocación de la antena se tenga una visión del horizonte 360º a la redonda.

La distancia máxima del receptor a la antena viene determinada fundamentalmente por dos factores:

- Ganancia de la antena elegida.
- Calidad del cable de antena. Se debe garantizar un nivel de pérdidas aceptable para la longitud deseada.

Debe tenerse cuidado en realizar el correcto acoplamiento de impedancias entre la entena, el cable y el receptor que en nuestro caso ha de ser de 75 ohm.

Por norma general, si se usa cable coaxial RG59, la distancia máxima entre antena y receptor no debería superar los 30 metros, con cables de mejor calidad (menores perdidas por metro) podríamos doblar e incluso triplicar esta distancia.

5.3 Elementos necesarios

Para la correcta instalación y funcionamiento del reloj son necesarios los siguientes elementos:

- Antena.
- Mástil o elemento de sujeción de la antena. (dependerá del tipo de antena elegido)
- Cable de antena, 75 ohm de impedancia y bajas perdidas.
- Disponibilidad de alimentación ya sea en continua o alterna según márgenes de alimentación. (ver especificaciones).

- Conector de alimentación tipo Red.
- Tornillos y tuercas de sujeción.

Si se desea cambiar la configuración por defecto programada de fábrica, también sería necesario un cable de datos y un ordenador con el software adecuado.

Otro elemento a tener en cuenta en toda instalación de antenas es un protector contra descargas atmosféricas tipo rayo. Si se opta por la instalación de uno de estos elementos, esté debería estar situado lo más cerca posible de la antena y disponer de una buena conexión a tierra para facilitar la descarga.

5.4 Instalación física

Para la correcta instalación del reloj se deberían seguir los siguientes pasos:

- Elegir la ubicación adecuada en un armario con mecánica de 19” o similar.
- Tener la precaución de conectar la tierra del equipo a la red de tierra de la instalación antes de alimentar la unidad.
- Colocar la antena y el cable correspondiente según se ha indicado anteriormente.
- Proceder a encender el equipo.

5.5 Recomendaciones y precauciones

Dado que este tipo de equipos están desarrollados para ser instalados en subestaciones eléctricas es necesario seguir las recomendaciones de seguridad de las empresas propietarias de la instalación, pero como norma general habrán de seguirse las siguientes precauciones:

- Durante las tormentas NO tocar antenas ni cables de antenas.
- Mantener la distancia de seguridad entra la antena y los cables de alta tensión.

- Desconectar la unidad cuando se manipule esta o la instalación de la antena.
- Verificar la correcta toma de tierra del equipo.
- El no cumplimiento de estas medidas de seguridad puede tener consecuencias fatales incluyendo la muerte.

GPS o un DSINCRO_TX, utilizando como medio físico la FO o el par trenzado (RS485) y los convertirá, en función de su configuración, a TTL (IRIGB003), RS232 (REE) y analógico (IRIGB123).

6. Interfaces

La versión estándar del reloj REAL-TIME GPS V02 dispone en su parte trasera de los interfaces necesarios para dar salida a los protocolos y señales generados por el reloj usados habitualmente, pero es posible bajo pedido suministrar otro tipo de combinaciones según las necesidades del cliente, como por ejemplo n número de salidas en FO con protocolo IRIGB, en protocolo REE o todas las salidas en TTL BNC.

Las características más destacables de cada salida se describen a continuación.

6.1 TTL

En TTL con conectorización BNC es posible disponer de:

- PPS
- IRIGB003/4
- Patrón de 1KHz.
- Pulsos Programados.

Todas estas salidas cuentan con un driver capaz de suministrar 100mA a una carga de 50 ohm.

La impedancia de salida es de 50 Ohm.

6.2 RS232

En RS232 con conectorización Sub-D 9 H solo se dispone de protocolo REE. El equipo cuenta con dos salidas de este tipo señalizadas como REE Y REE2.

Estas salidas están protegidas contra sobretensiones mediante un diodo supresor de transitorios; además el driver RS232 está aislado galvánicamente del resto de la electrónica mediante un optoacoplador rápido y un convertidor DC/DC.

6.3 RS485

En RS485 y mediante conectores enchufables de tres vías (A, B y T) es posible disponer:

- IRIGB003/4
- REE
- PPS (opción)
- Pulsos Programados (opción)

Esta salida está protegida contra sobretensiones mediante diodos supresores de transitorios y fusibles rearmables, además el driver RS485 está aislado galvánicamente del resto de la electrónica mediante un optoacoplador rápido y un convertidor DC/DC.

Mediante los jumpers JP2 y JP9 se puede habilitar una resistencia terminadora de bus de 120 ohm, además cuenta con jumpers que habilitan sendas resistencias de pull-up y pull-down cuando se requiera.

6.4 Fibra óptica

En Fibra Óptica (FO) multimodo y mediante conectores ST es posible disponer:

- IRIGB003/4
- REE
- PPS (opción)
- Pulsos Programados (opción)

Esta salida en Fibra Óptica es de 820 nm de longitud de onda, con posibilidad de usar Fibra Óptica multimodo de 50/125 µm, 62.5/125 µm, 100/140 µm. La velocidad máxima de trabajo se sitúa en 5 Mbps con un alcance efectivo de 2500 metros.

6.5 Relé auxiliar

El reloj cuenta con un relé interno para señalizar a un equipo externo el estado operativo del reloj.

En condiciones óptimas de funcionamiento relé está activo pasando a reposo ante cualquier problema hardware que afecte al correcto funcionamiento del equipo; estos problemas pueden ser:

- Consumo de la antena fuera de margen.
- Antena desconectada.
- Tensión en antena fuera de margen.
- Tensión de la batería baja
- Error de comunicaciones con el receptor GPS.
- Equipo apagado

7. Configuración

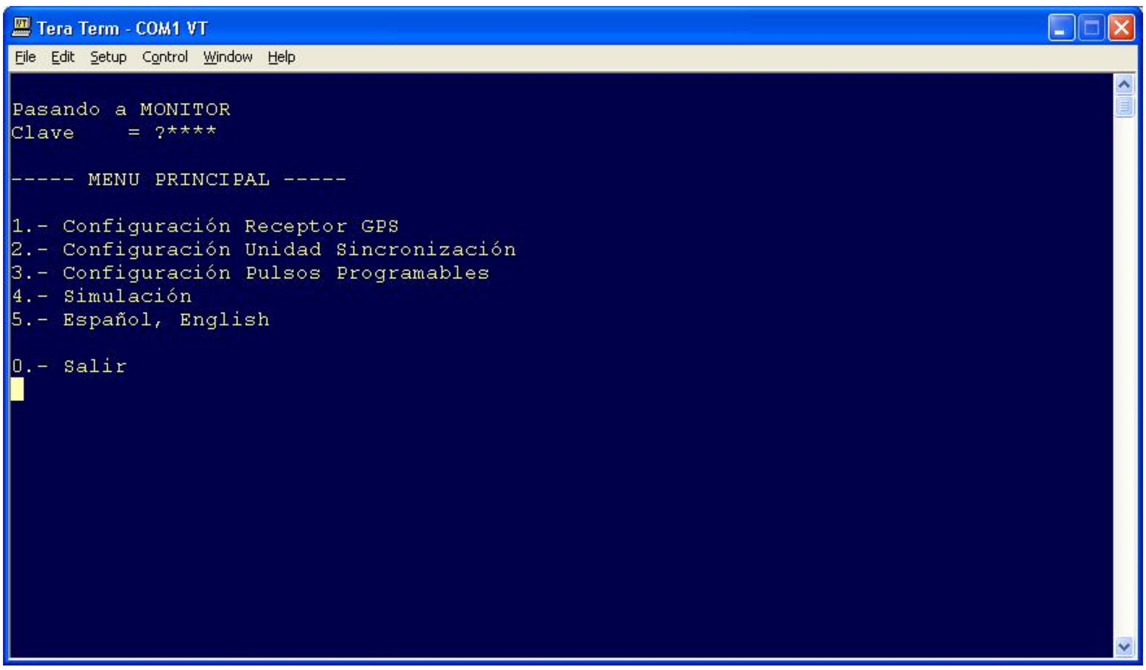
El REAL-TIME GPS V02 sale de fábrica con una configuración que le permite funcionar en cualquier nueva instalación, por lo que en principio no es necesario ningún tipo de ajuste, no obstante es posible modificar los parámetros de configuración entrando en MODO MONITOR y navegando por los menús. Cualquier cambio que realicemos no será efectivo hasta que no confirmemos dicho cambio y salgamos del MODO MONITOR.

Como ya se indicó en el apartado 2.1 CARACTERISTICAS, para entrar en modo “MONITOR” es necesario un programa emulador de terminal como el Hyperterminal, una vez que hayamos configurado el puerto serie de nuestro ordenador (9600bps, 8 bit de datos, 1 bit de stop y sin paridad) nos conectaremos al conector frontal y pulsaremos la tecla “ESC”, el reloj nos pedirá que introduzcamos la PASSWORD para acceder a los menús y al cambio de idioma.

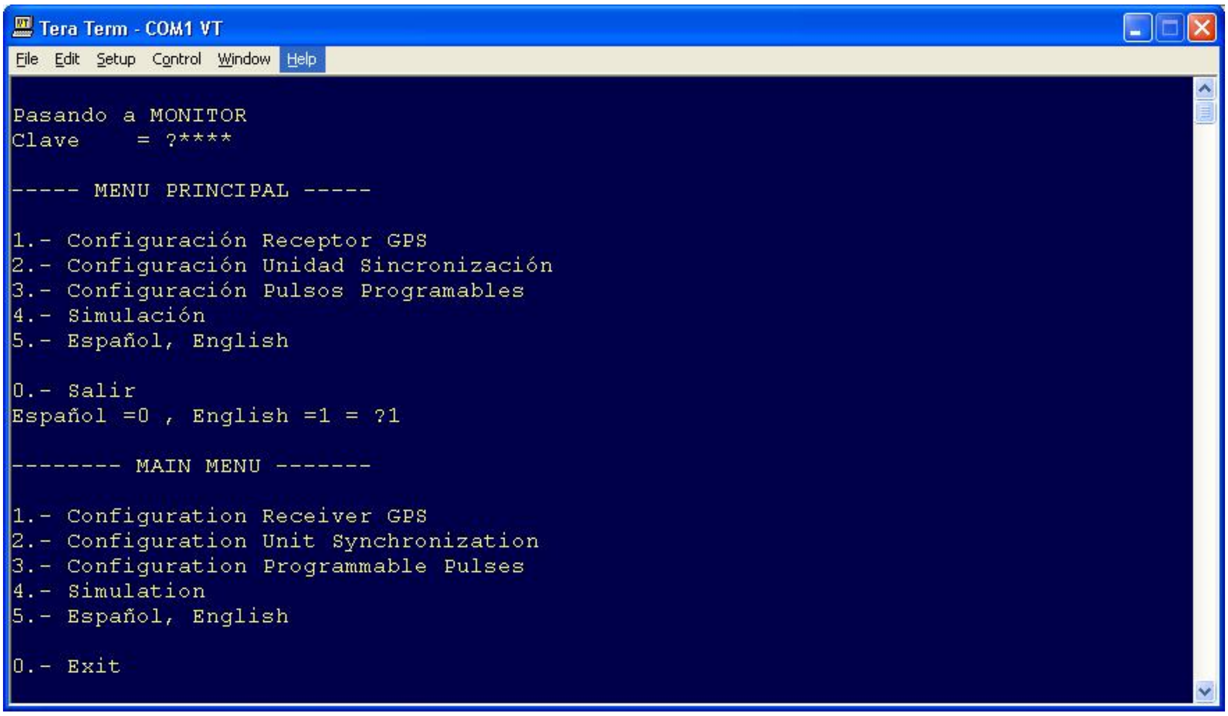
De fabrica el equipo sale con la PASWORD por defecto a “1234”

7.1 Menú principal (idioma)

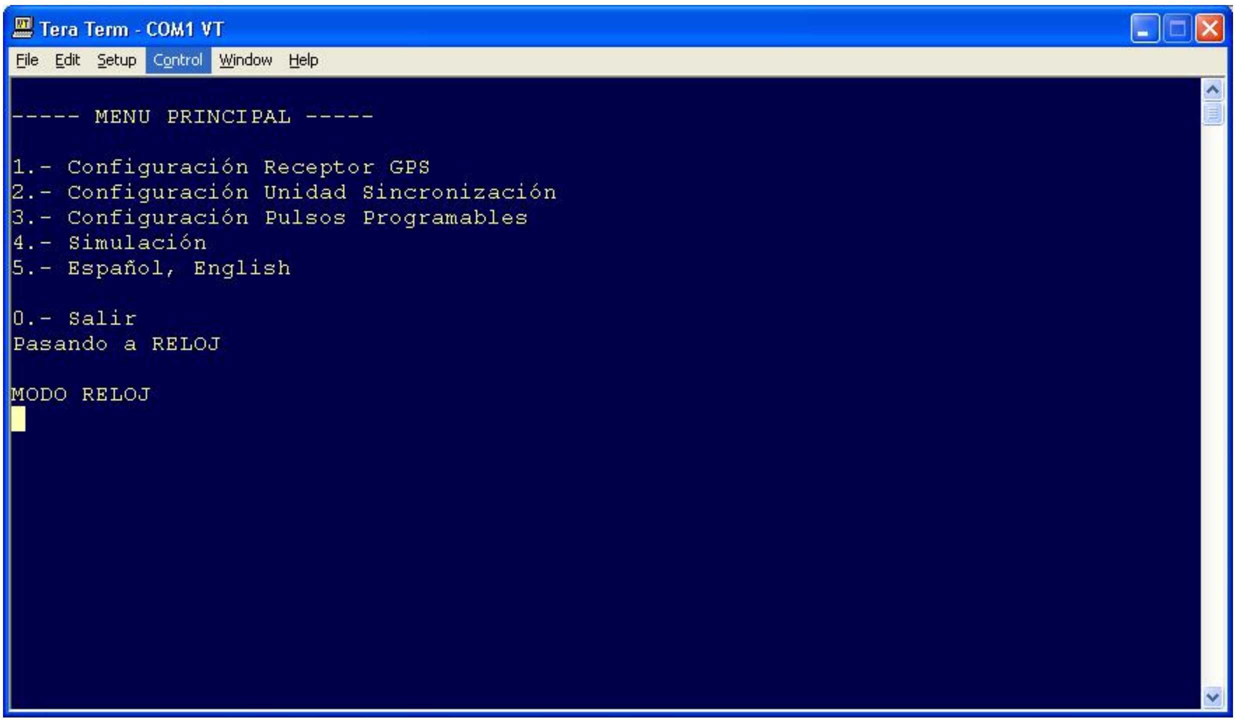
Desde este menú tenemos la posibilidad de acceder al resto de menús.



O cambiar el idioma.

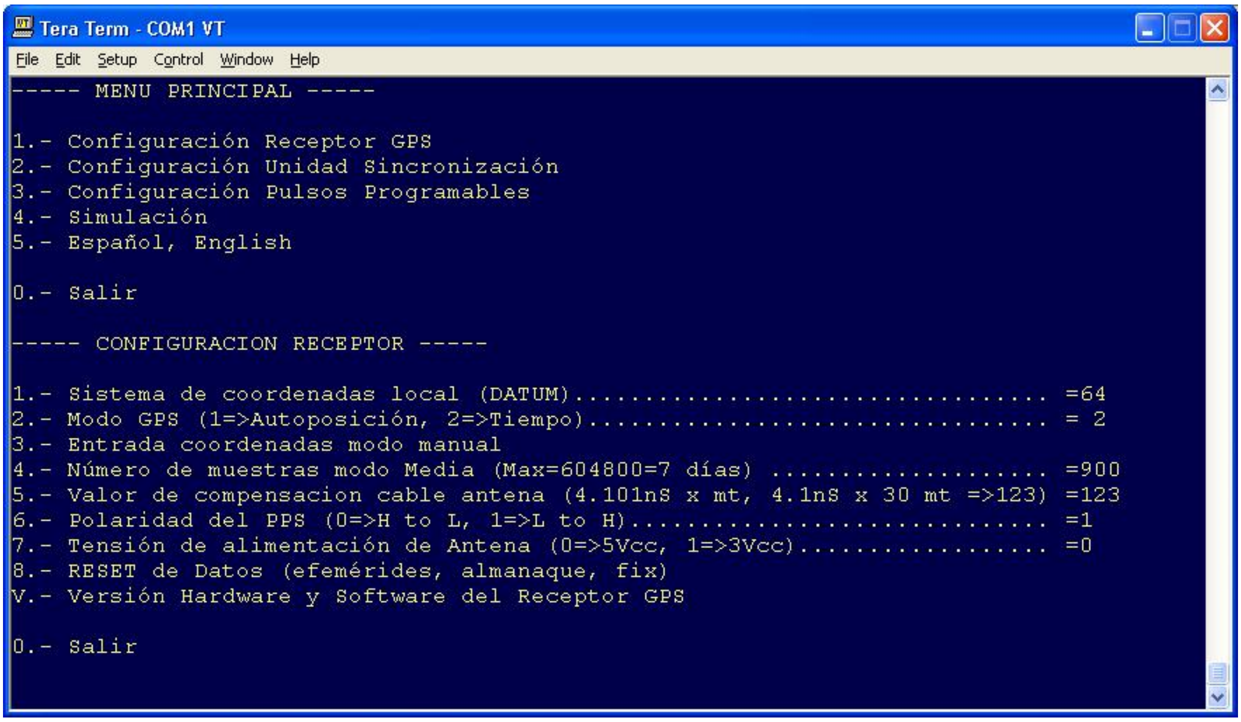


O salir del MODO MONITOR al MODO RELOJ.



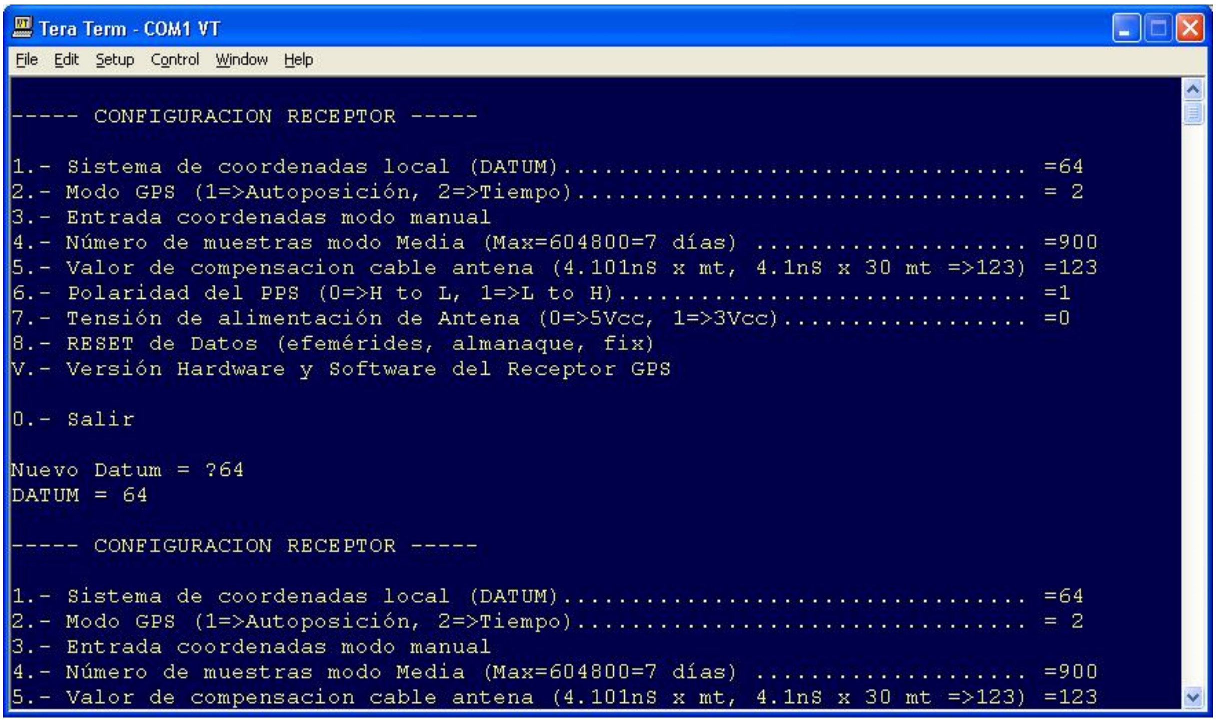
7.2 Configuración receptor GPS

Este menú permite configurar y visualizar los parámetros más significativos del receptor.



7.2.1 Sistema de coordenadas local

Sistema de coordenadas local o DATUM es un parámetro que le indica al receptor GPS las correcciones necesarias para cada punto de la Tierra en relación a modelo “0” (WGS84). Para el caso de España y Portugal el valor es 64. Ver dentó del Anexo II “DATUMS”

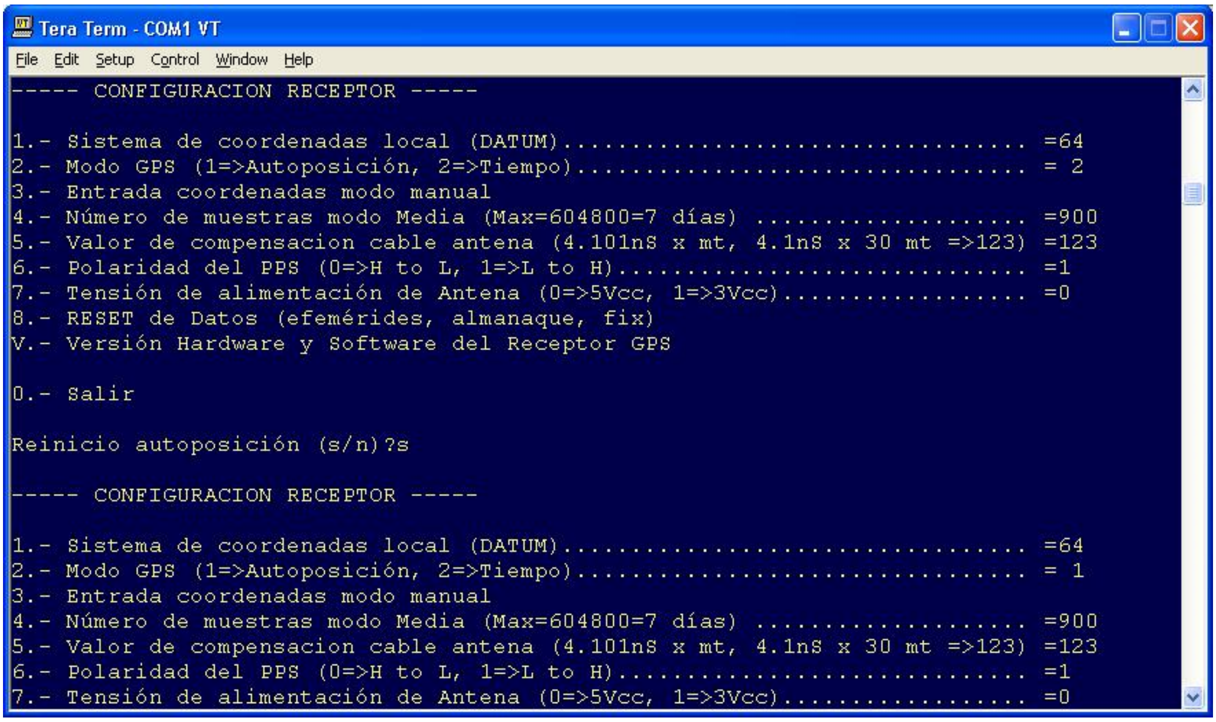


7.2.2 Modo de salida PPS

Configura el modo de trabajo del PPS, pudiendo darse los valores siguientes:

1- AUTOPOSICION, en este modo se reinicia el cálculo de la posición sacando la media de un determinado número de muestras fijadas por el valor introducido en la opción 4.-

2- TIEMPO, es este modo se supone que disponemos de unas coordenadas de posición buenas. A este modo se pasa automáticamente desde el punto anterior.



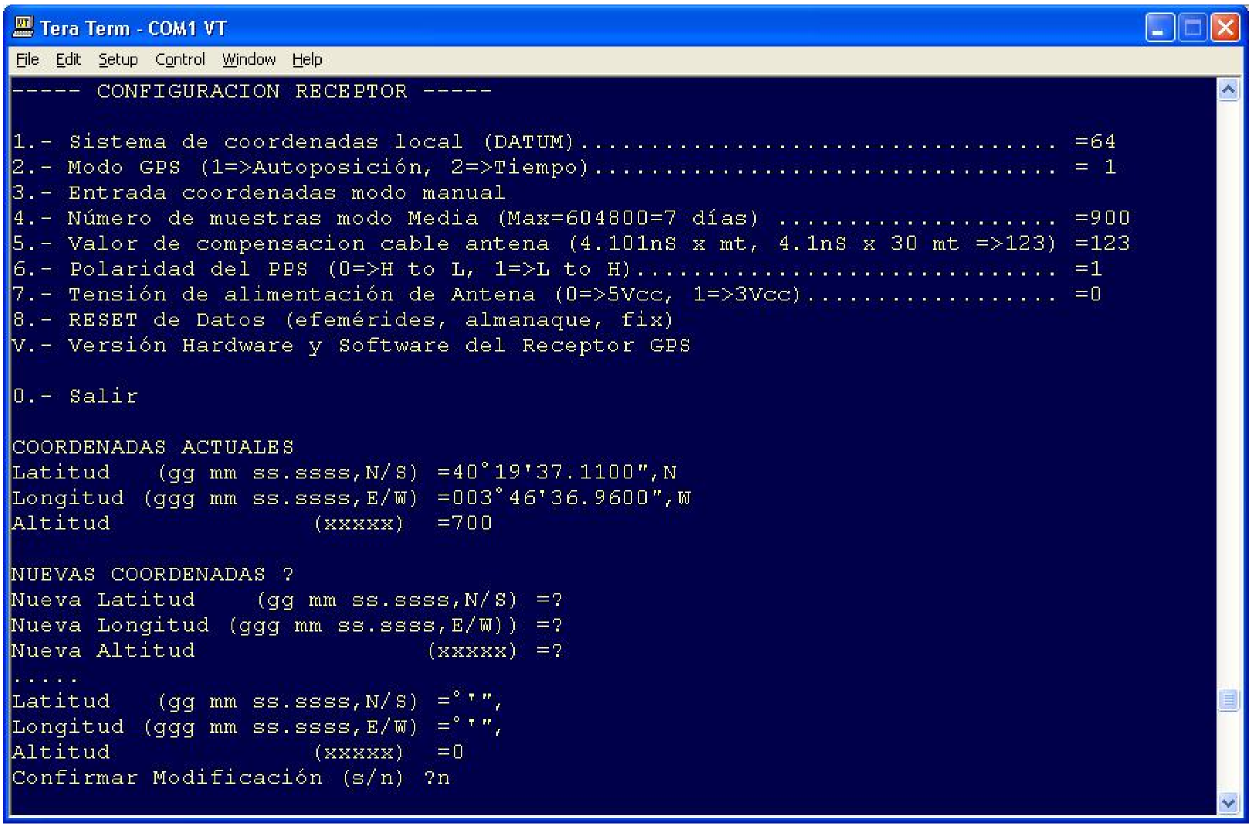
En nuestro caso la configuración por defecto es "1", de tal manera que cuando el receptor GPS haya completado un número de posicionamientos programado (Apartado 7.2.4) se pasara a modo TIEMPO.

7.2.3 Entrada de coordenadas en modo MANUAL

Existen dos modos de introducir las coordenadas geográficas dentro del receptor para que este trabaje en modo TIEMPO:

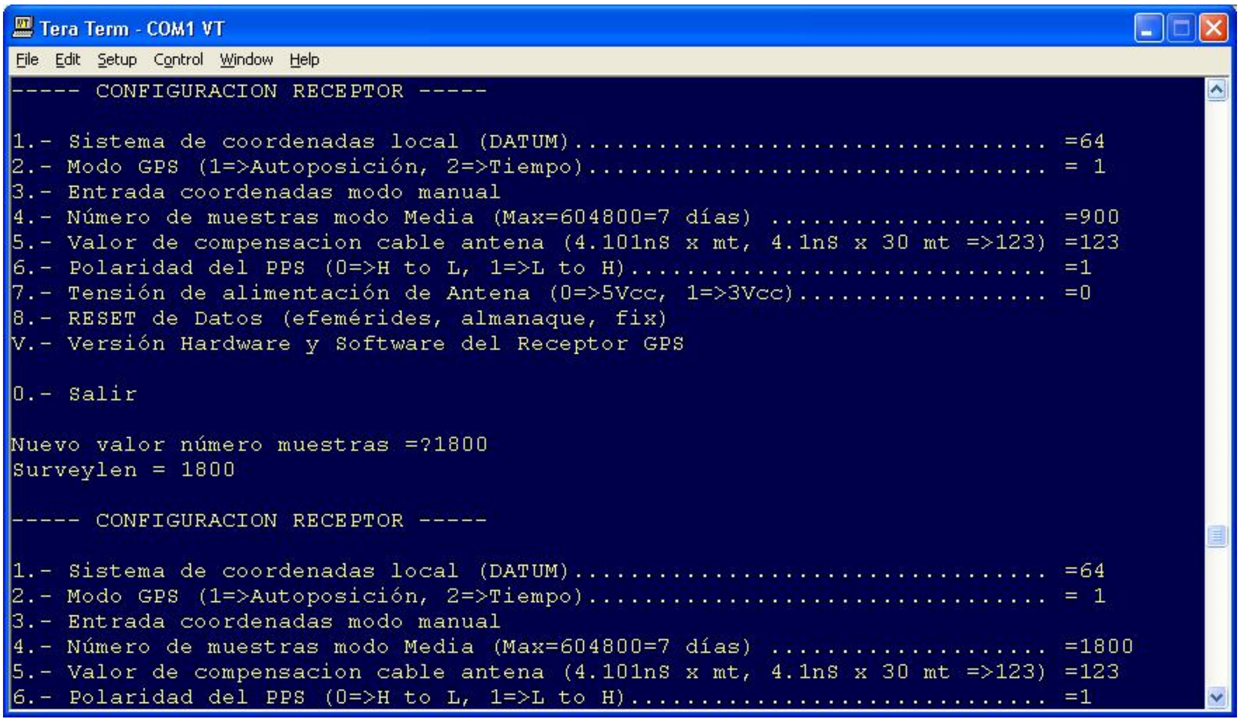
- De manera automática, al pasar del modo AUTOPOSICION a modo TIEMPO, después de que se haya completado el número de posicionamientos programado.
- De manera manual, como se indica.

Entrando en este apartado podremos ver las coordenadas que tiene el receptor previamente calculadas o introducidas manualmente.



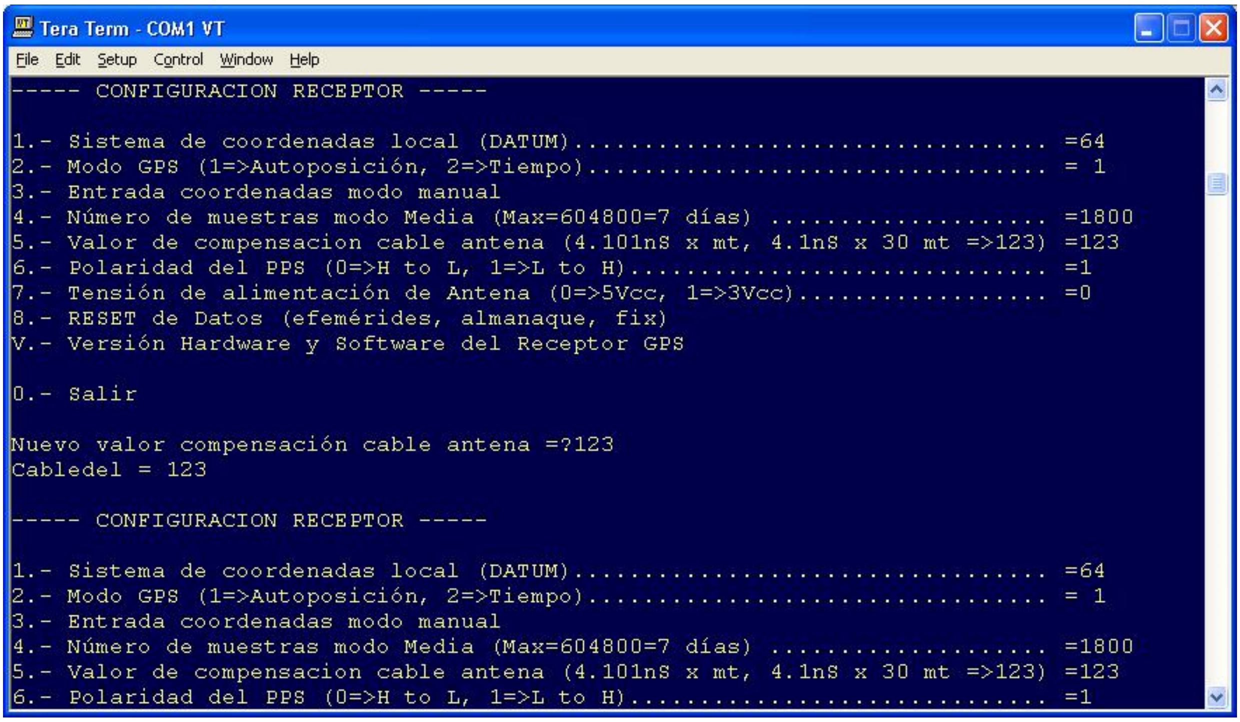
7.2.4 Numero de muestras en modo AUTOPOSICION

Indica al receptor en número de posicionamientos que tiene que calcular antes de pasarse a modo TIEMPO, teniendo en cuento que en condiciones óptimas, es decir con al menos 4 satélites a la vista, se genera un posicionamiento por segundo.



7.2.5 Valor de compensación cable antena

Con objeto de corregir el retraso de la propagación de la señal desde la antena al GPS, es posible introducir un parámetro de corrección. El retraso introducido por un metro de cable de antena corresponde a 4.1 ns, por lo que 30 metros le corresponden 123 ns.

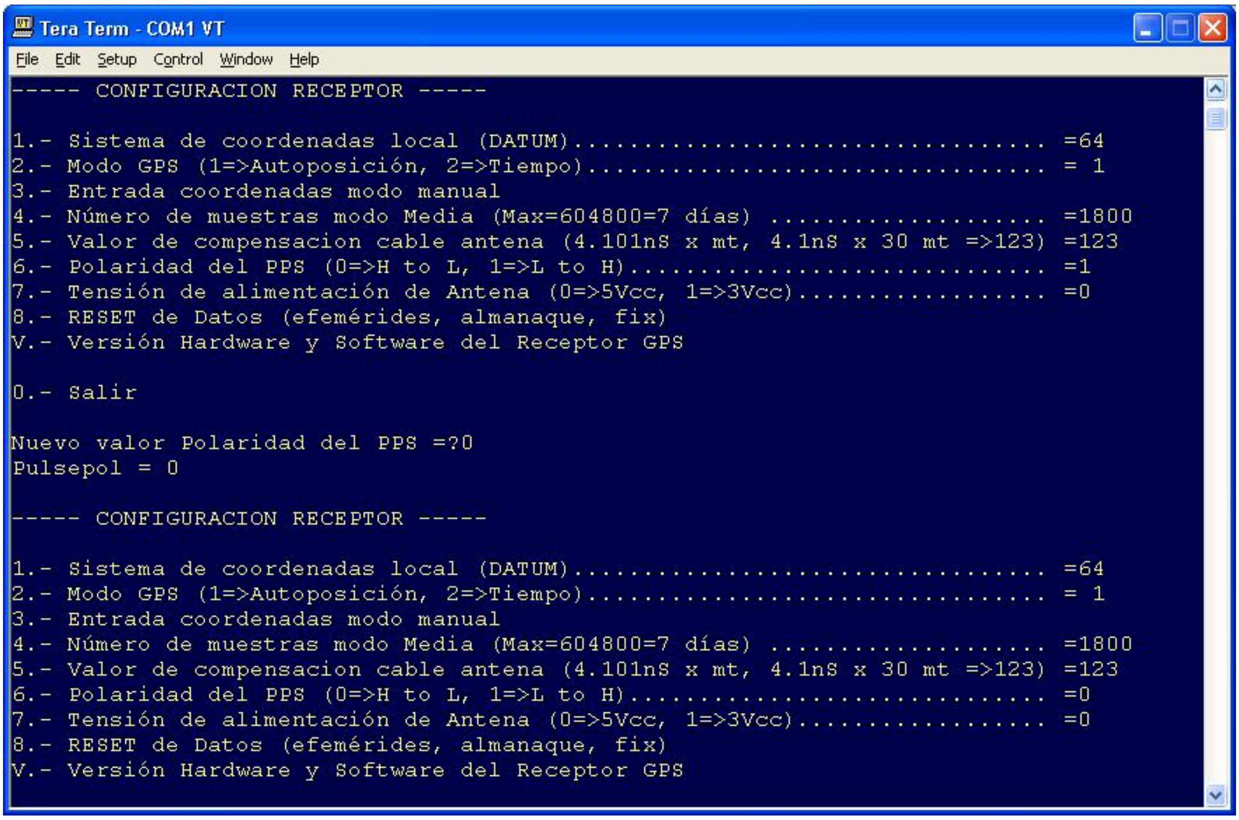


7.2.6 Polaridad PPS

Con este parámetro se le indica al receptor la polaridad del PPS y por lo tanto cual es el flanco activo.

Si la polaridad es 0, el flanco activo es el de bajada.

Si la polaridad es 1, el flanco activo es el de subida.



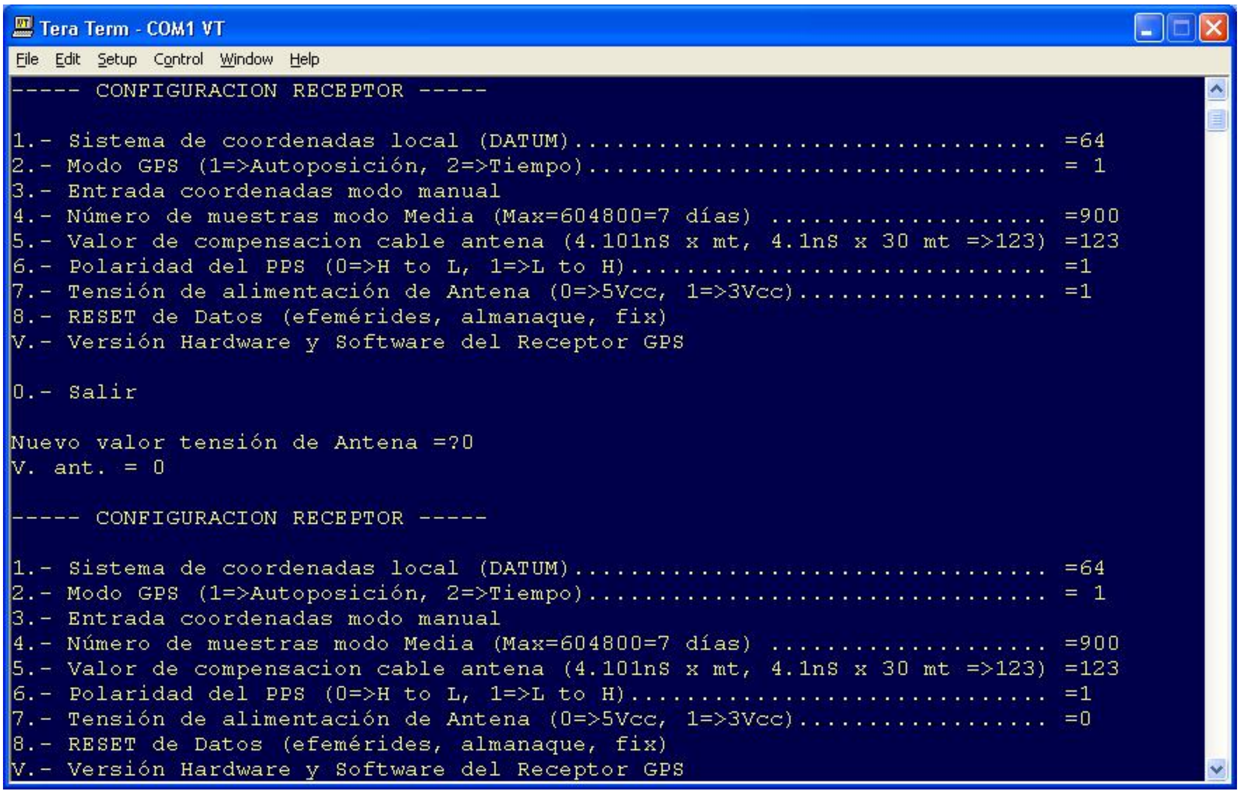
Este parámetro no influye sobre la salida física de PPS que se configura por hardware.

7.2.7 Reset de datos

Debido a la gran variedad de antenas que pueden ser conectadas al receptor GPS, ha sido necesario disponer de un mecanismo que permita elegir la tensión de alimentación de la antena. Los valores pueden ser:

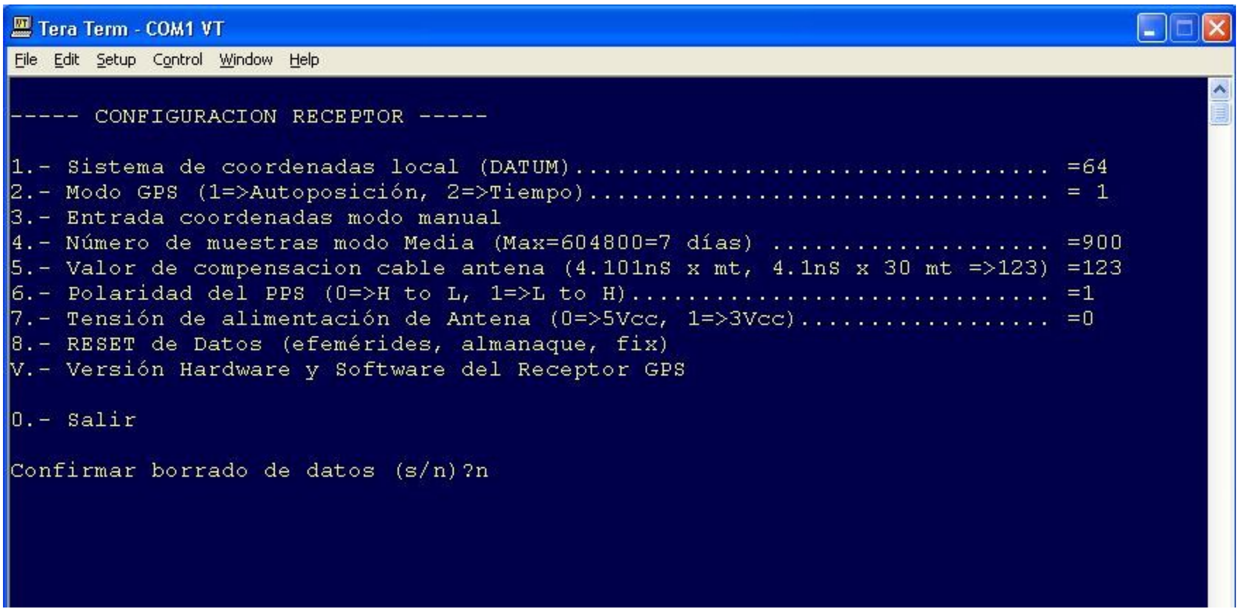
0- Tensión de alimentación de 5 Vcc.

1- Tensión de alimentación de 3 Vcc.



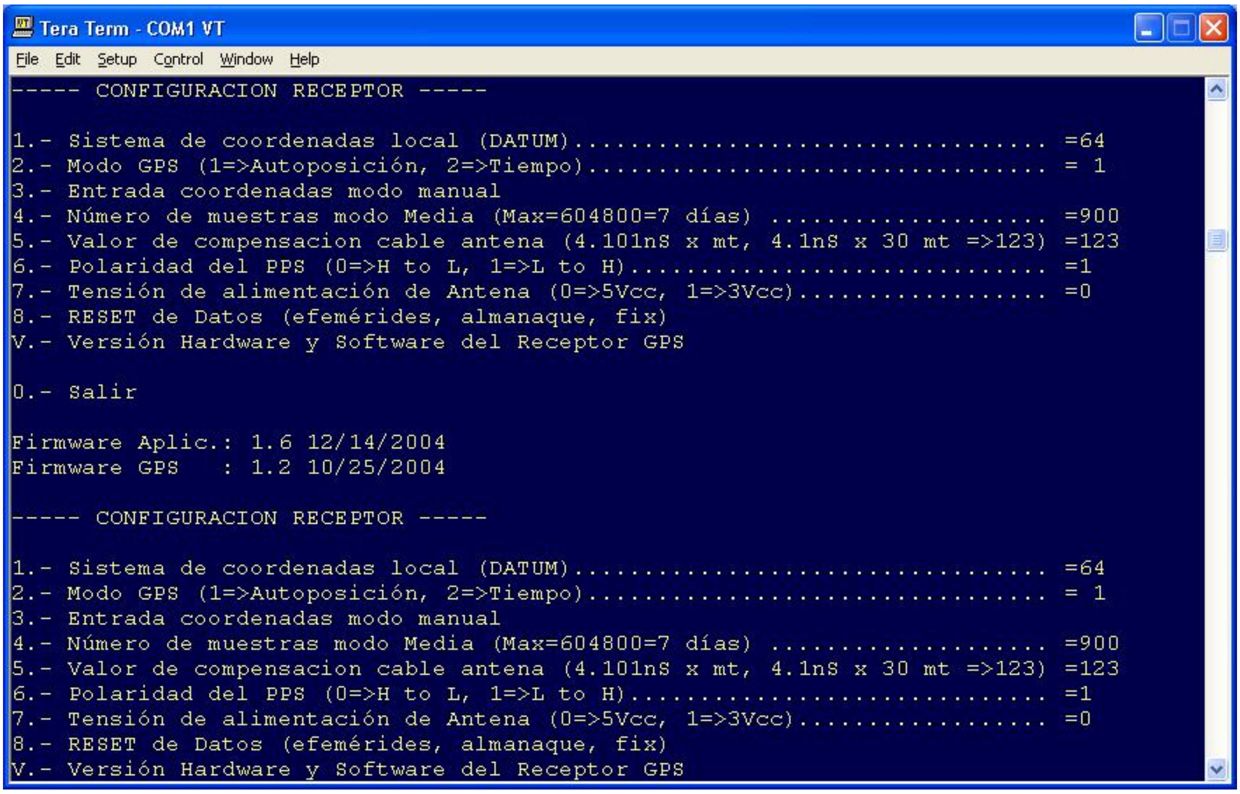
7.2.8 Reset de datos

Durante el funcionamiento del receptor GPS, esté almacena diversa información referente a la situación de los satélites en el espacio, así como otros parámetros, existe la posibilidad de hacer un borrado de está, con objeto de que sea adquirida de nuevo por el receptor.



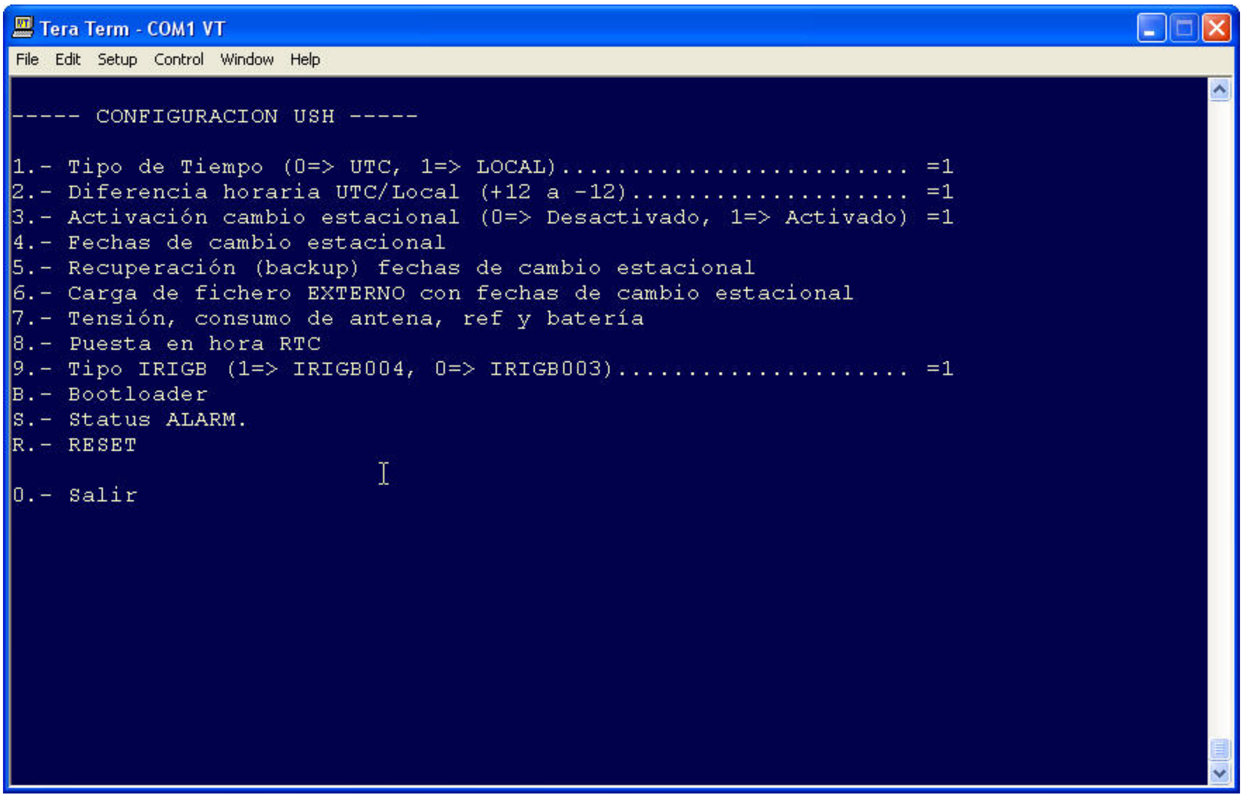
7.2.9 Versión Hardware y Software del receptor GPS

El receptor GPS es un equipo que tiene su propio software, mediante esta función es posible conocer la versión.



7.3 Configuración Unidad de Sincronización.

Este menú permite configurar y visualizar los parámetros del reloj.

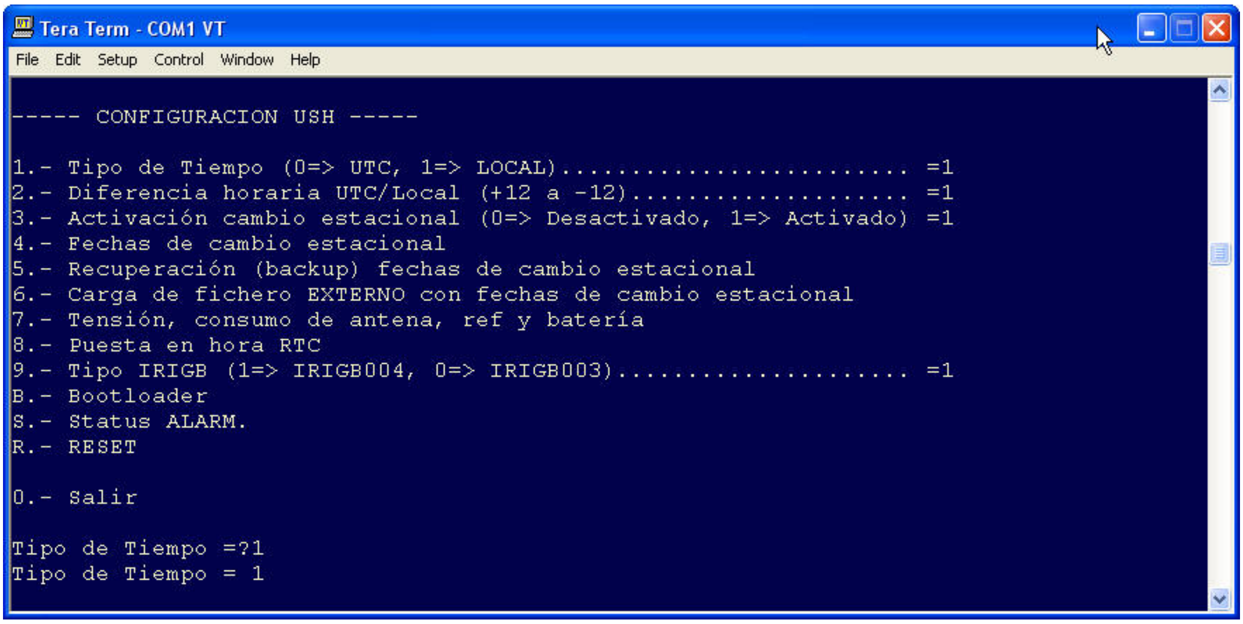


7.3.1 Tipo de Tiempo

Como ya hemos dicho, el tiempo proporcionado por el receptor GPS es tiempo UTC, pero dependiendo del país donde este ubicado el reloj necesitamos sumar o restar un determinado número de horas para que la hora proporcionada por el reloj se ajuste a la hora local o huso horario.

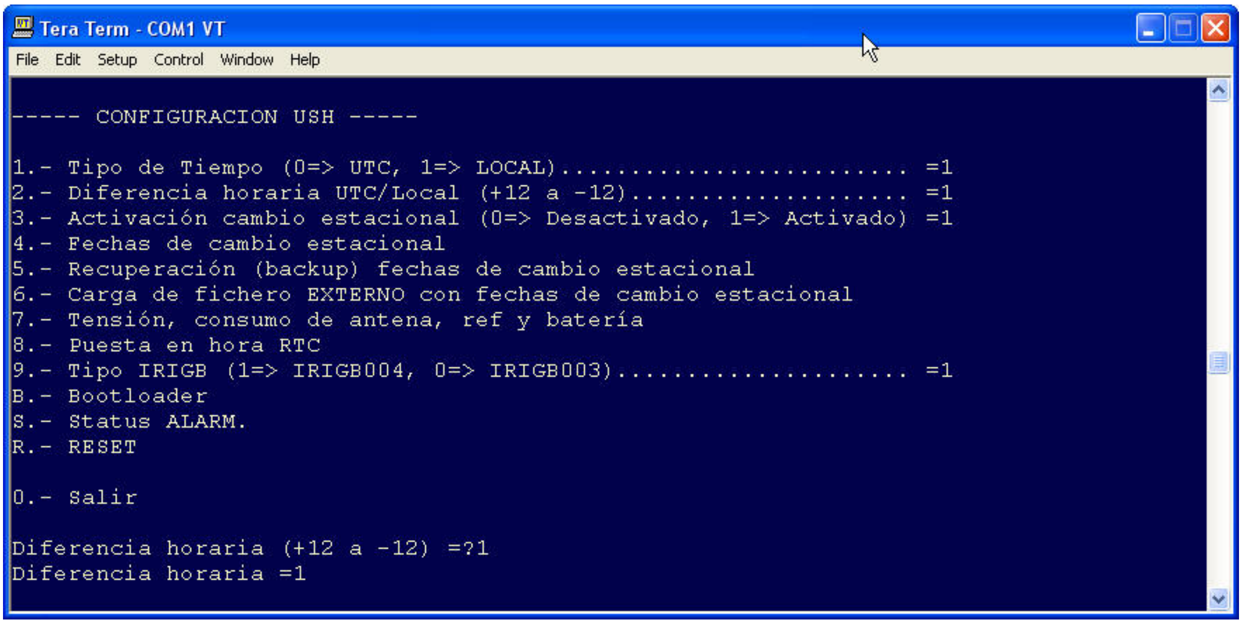
Ajustando este parámetro indicamos si vamos a trabajar con la hora UTC o con la hora Local.

0- Hora UTC.
1- Hora Local.



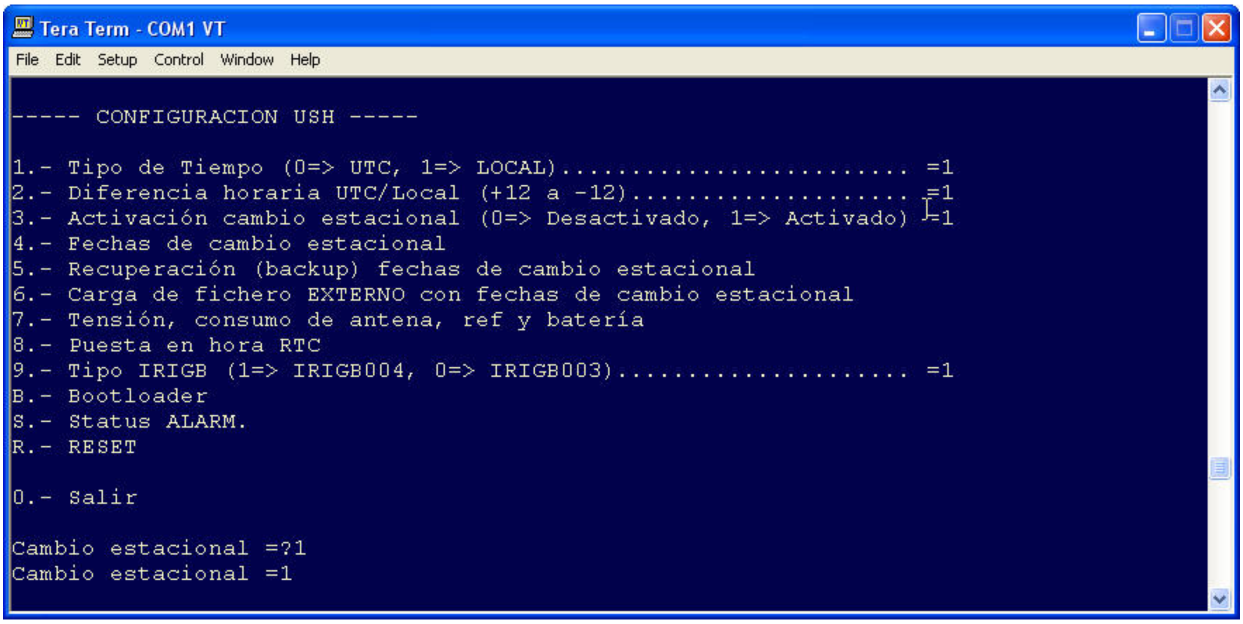
7.3.2 Diferencia horaria UTC/Local

De lo dicho en el apartado anterior se deduce que con este parámetro indicamos la diferencia horaria entre la hora UTC y la hora Local.



7.3.3 Activación cambio estacional

Además de la diferencia entre la hora UTC y la hora Local, habrá que tener en cuanta si en la ubicación del reloj se producen cambios horarios estaciónales, con este parámetro se le indica al reloj si debe tener en cuanta esta circunstancia.

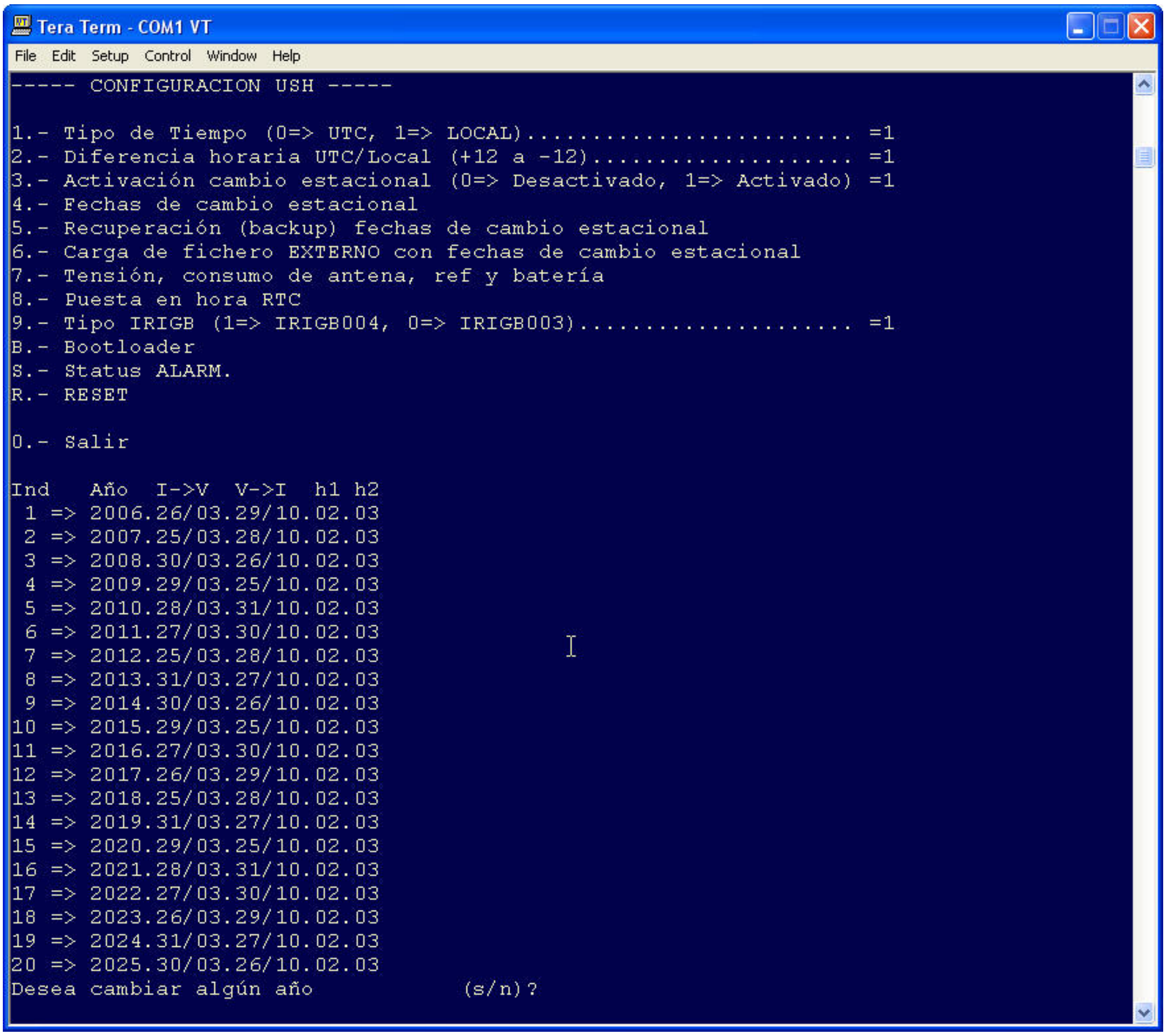


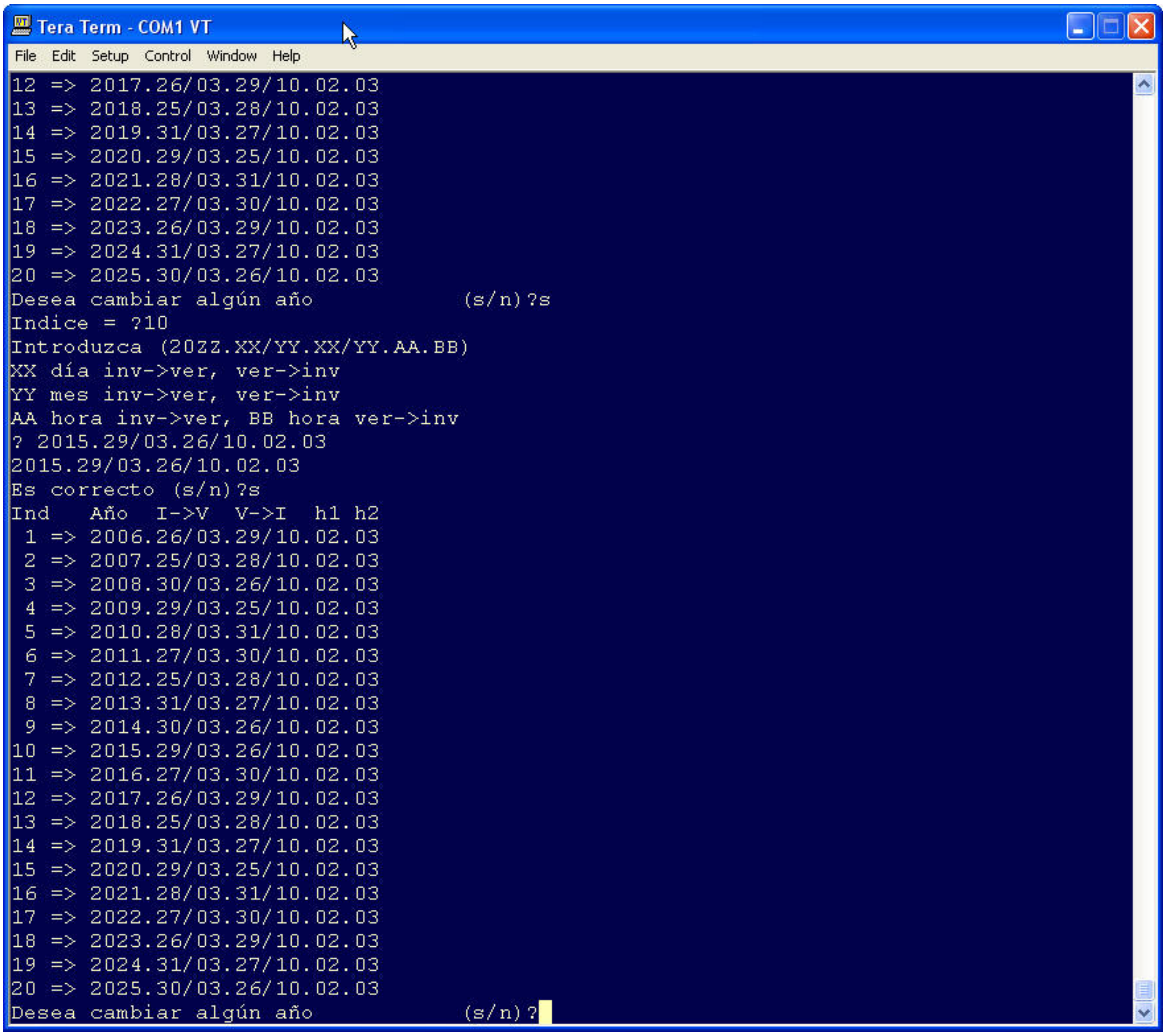
7.3.4 Cambio de fechas cambio estacional

Por defecto el reloj viene configurado con 20 años de cambios horarios estaciónales, que son acordes con las directivas de la Unión Europea referente a esta materia.

La codificación viene indicada por: Año, día del mes del cambio invierno a verano, día del mes del cambio verano a invierno, hora local del cambio invierno a verano y hora local del cambio verano a invierno.

Es posible la modificación de cualquiera de las fechas de cambio como se ve en la figura.

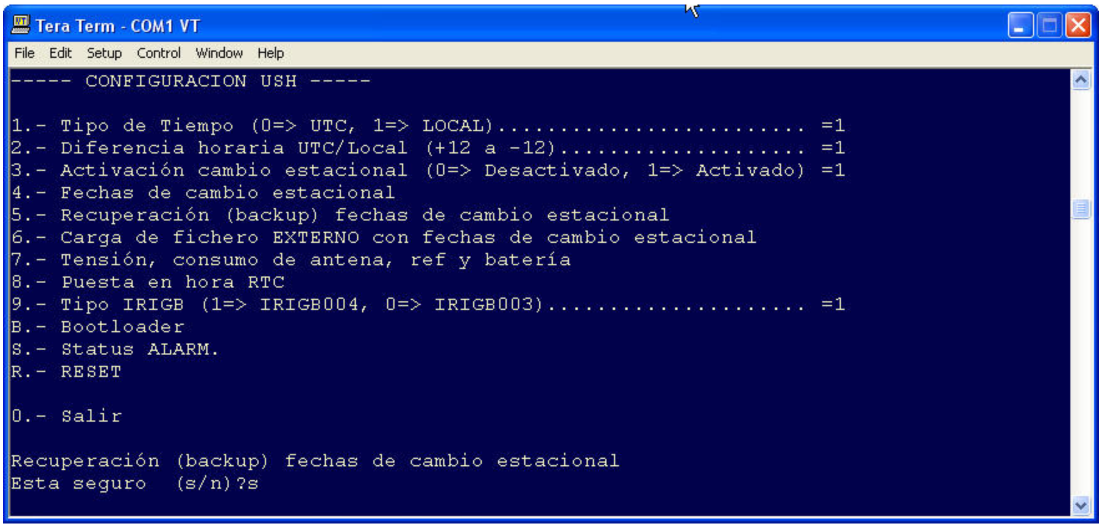




```
Tera Term - COM1 VT
File Edit Setup Control Window Help
12 => 2017.26/03.29/10.02.03
13 => 2018.25/03.28/10.02.03
14 => 2019.31/03.27/10.02.03
15 => 2020.29/03.25/10.02.03
16 => 2021.28/03.31/10.02.03
17 => 2022.27/03.30/10.02.03
18 => 2023.26/03.29/10.02.03
19 => 2024.31/03.27/10.02.03
20 => 2025.30/03.26/10.02.03
Desea cambiar algún año            (s/n)?s
Indice = ?10
Introduzca (20ZZ.XX/YY.XX/YY.AA.BB)
XX día inv->ver, ver->inv
YY mes inv->ver, ver->inv
AA hora inv->ver, BB hora ver->inv
? 2015.29/03.26/10.02.03
2015.29/03.26/10.02.03
Es correcto (s/n)?s
Ind   Año   I->V  V->I  h1 h2
 1 => 2006.26/03.29/10.02.03
 2 => 2007.25/03.28/10.02.03
 3 => 2008.30/03.26/10.02.03
 4 => 2009.29/03.25/10.02.03
 5 => 2010.28/03.31/10.02.03
 6 => 2011.27/03.30/10.02.03
 7 => 2012.25/03.28/10.02.03
 8 => 2013.31/03.27/10.02.03
 9 => 2014.30/03.26/10.02.03
10 => 2015.29/03.26/10.02.03
11 => 2016.27/03.30/10.02.03
12 => 2017.26/03.29/10.02.03
13 => 2018.25/03.28/10.02.03
14 => 2019.31/03.27/10.02.03
15 => 2020.29/03.25/10.02.03
16 => 2021.28/03.31/10.02.03
17 => 2022.27/03.30/10.02.03
18 => 2023.26/03.29/10.02.03
19 => 2024.31/03.27/10.02.03
20 => 2025.30/03.26/10.02.03
Desea cambiar algún año            (s/n)?
```

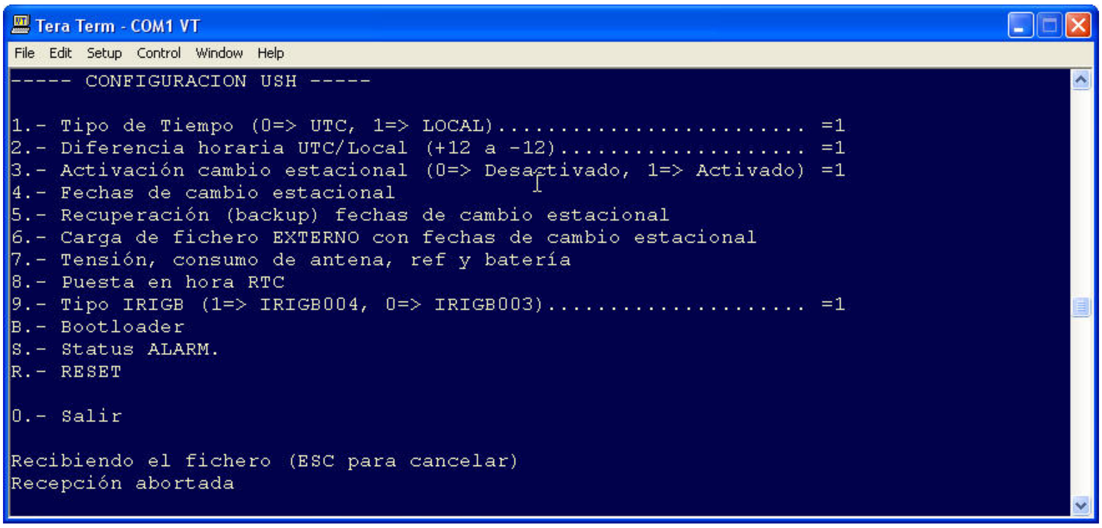
7.3.5 Recuperación backup fechas cambio estacional por defecto

Si hemos cometido un error o varios en el apartado anterior, podemos volver a cargar las fechas por defecto mediante esta función, con lo que volveremos a la situación inicial.



7.3.6 Carga de fichero externo

También es posible cargar nuestros ajustes de cambio estacional mediante un fichero externo que ha de tener una estructura determinada, en cualquier caso, después de efectuada la carga se nos pedirá confirmación de si los datos cargados son correctos o no.



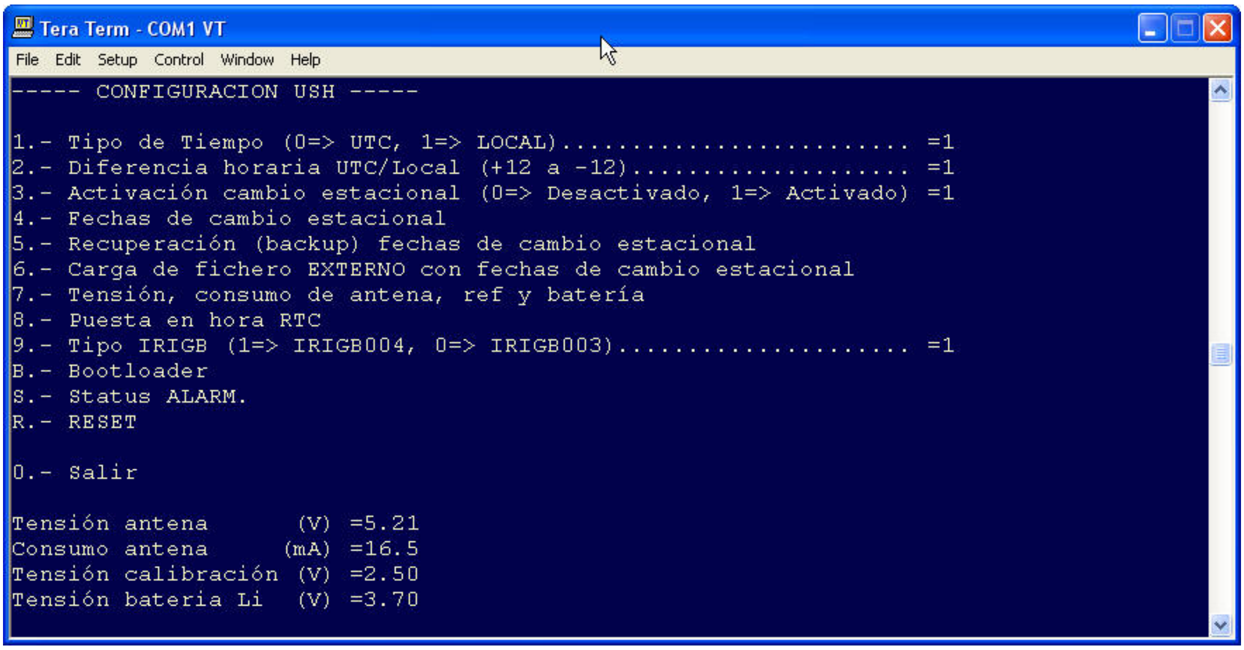
El fichero es un fichero de texto plano cuyo aspecto es el siguiente

06.26/03.29/10.02.03.
07.25/03.28/10.02.03.
08.30/03.26/10.02.03.
09.29/03.25/10.02.03.
10.28/03.31/10.02.03.
11.27/03.30/10.02.03.
12.25/03.28/10.02.03.
13.31/03.27/10.02.03.
14.30/03.26/10.02.03.
15.29/03.25/10.02.03.
16.27/03.30/10.02.03.
17.26/03.29/10.02.03.
18.25/03.28/10.02.03.
19.31/03.27/10.02.03.
20.29/03.25/10.02.03.
21.28/03.31/10.02.03.
22.27/03.30/10.02.03.
23.26/03.29/10.02.03.
24.31/03.27/10.02.03.
25.30/03.26/10.02.03.

En nuestro caso el fichero de denomina “tabla.txt” y puede ser enviado al reloj mediante el mismo programa emulador de terminal, indicando que es un fichero de texto.

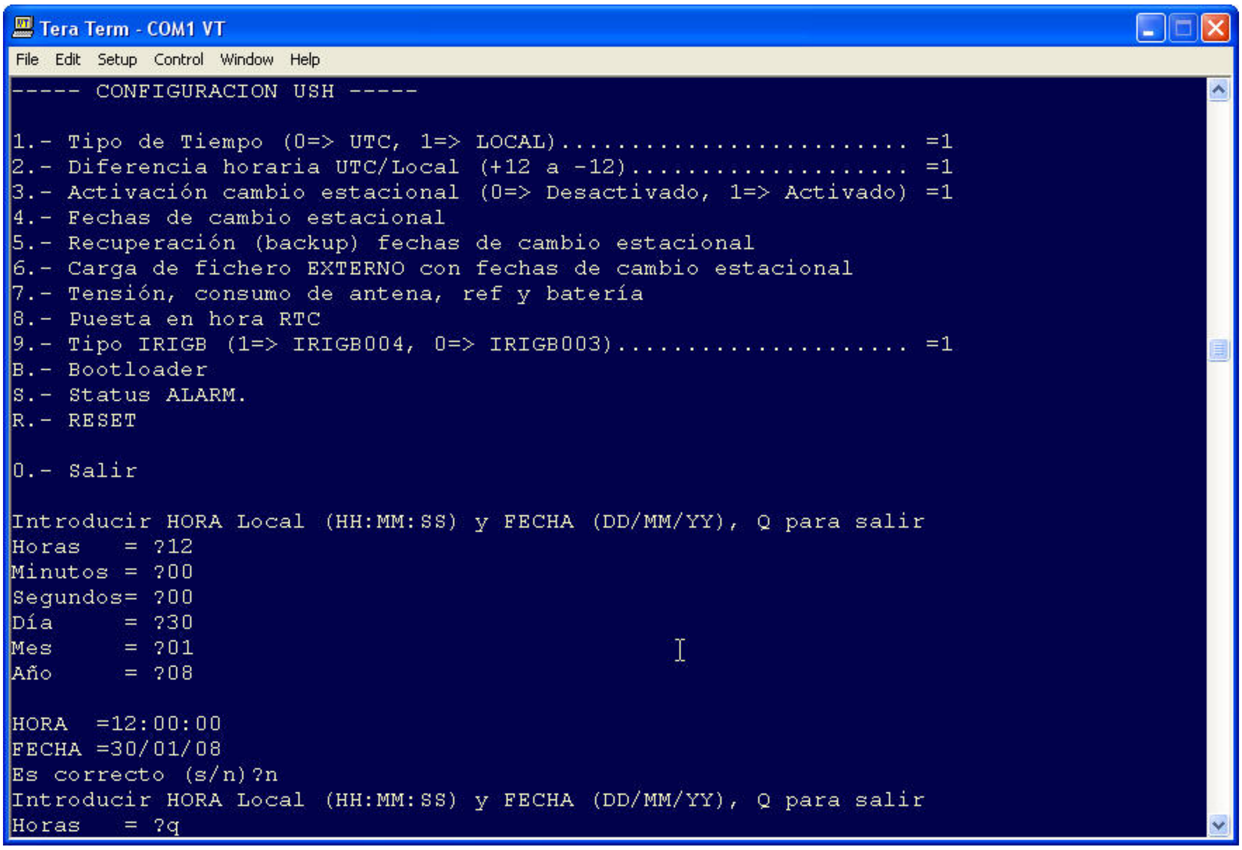
7.3.7 Visualización de tensiones y consumos

Con este comando es posible visualizar la tensión presente en la antena, así como el consumo de esta, la tensión de calibración del micro y la tensión de la batería de Litio del reloj RTC.



7.3.8 Puesta en hora RTC

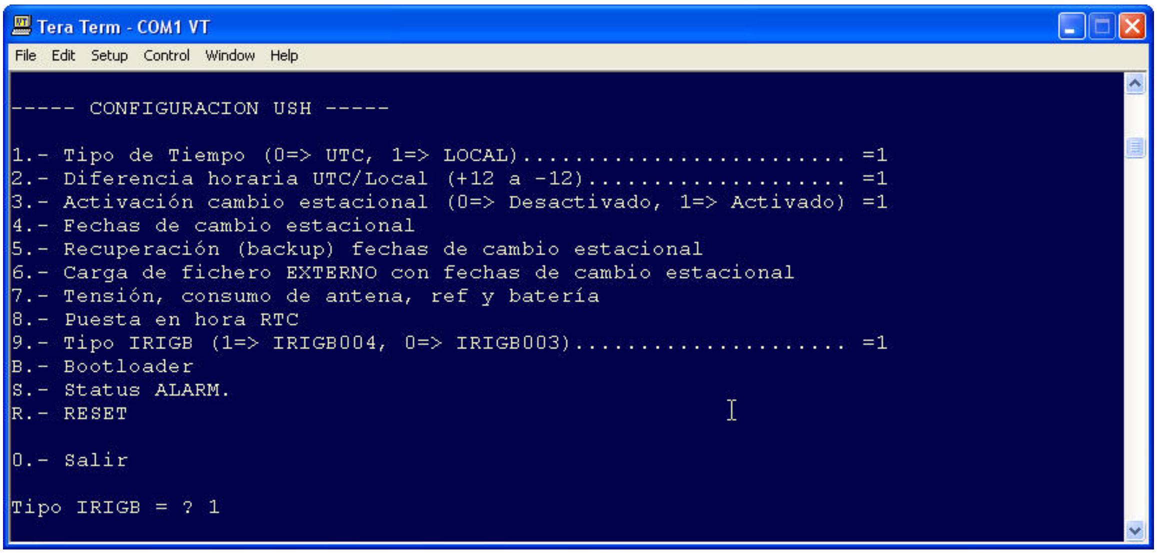
La puesta en hora del RTC es automática desde el momento en que tenemos el reloj sincronizado por GPS, pero existe la posibilidad de introducirla manualmente. ¿En qué circunstancias se hace esto? Cuando el reloj se instala por primera vez puede que no tenga el RTC en hora, esto retrasara el proceso de adquisición de satélites por parte del receptor GPS.



7.3.9 Tipo de IRIGB

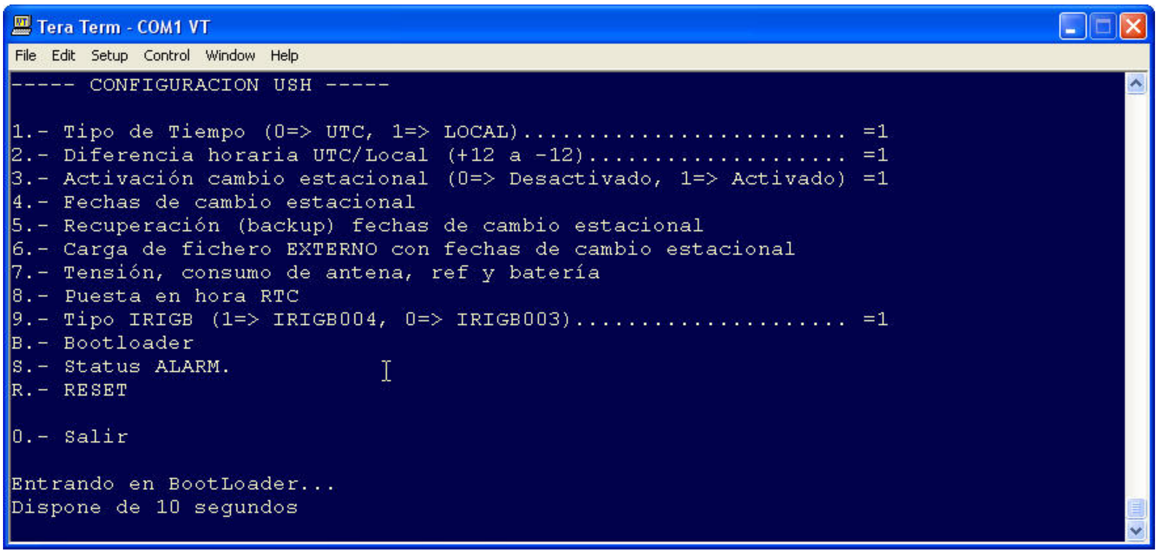
Con esta opción seleccionamos el tipo de salida de IRIGB, por defecto esta seleccionado el formato IRIGB004/124.

La opción IRIGB003/123 se mantiene por compatibilidad con versiones anteriores.



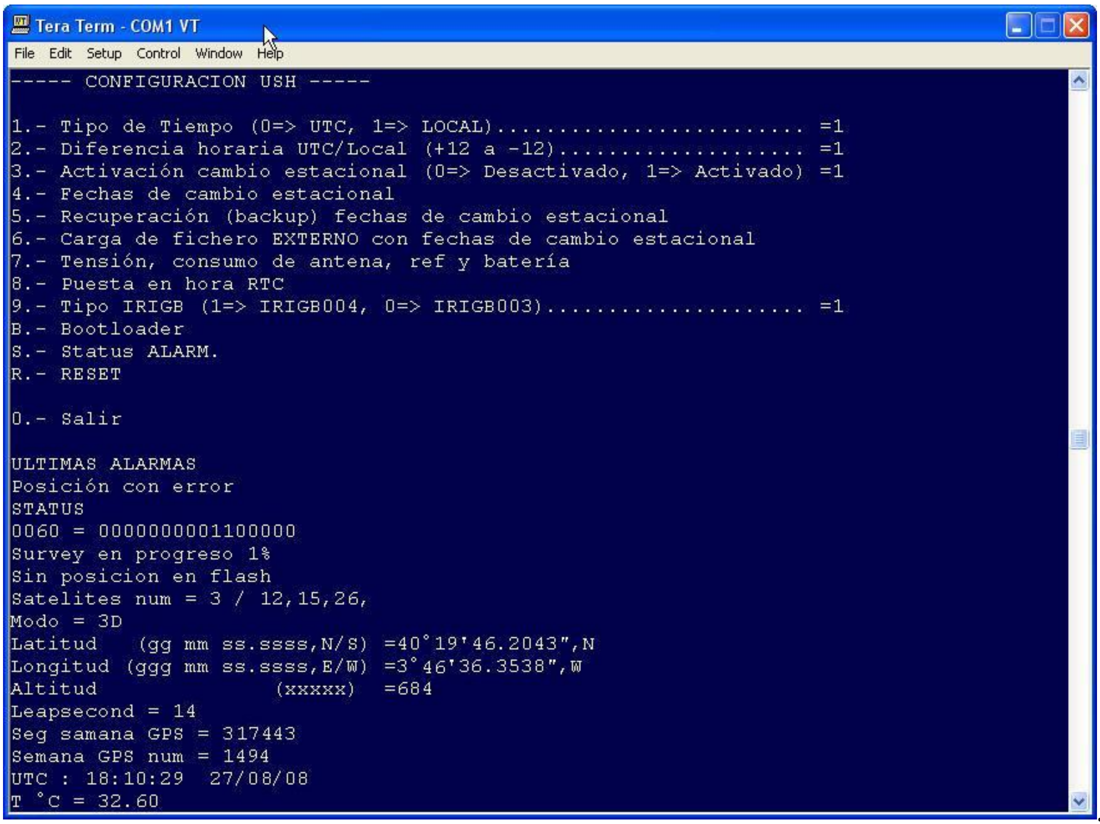
7.3.10 Carga de Firmware

Entrando en la opción Bootloader es posible, si se tiene la herramienta adecuada, cambiar el Firmware del reloj, de esta manara se pueden añadir nuevas funcionalidades o corregir algún vicio oculto sin necesidad de desmontar la unidad de su ubicación.



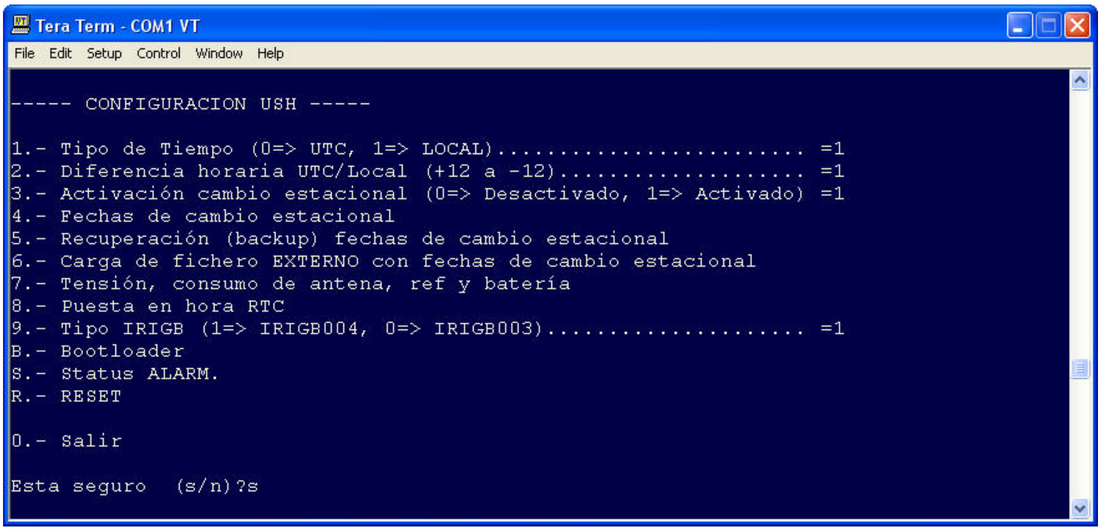
7.3.11 Status ALARM

Entrando en esta opción podremos ver en que situación funcional se encuentra el equipo y ver si tiene algún tipo de alarma además de otros datos.



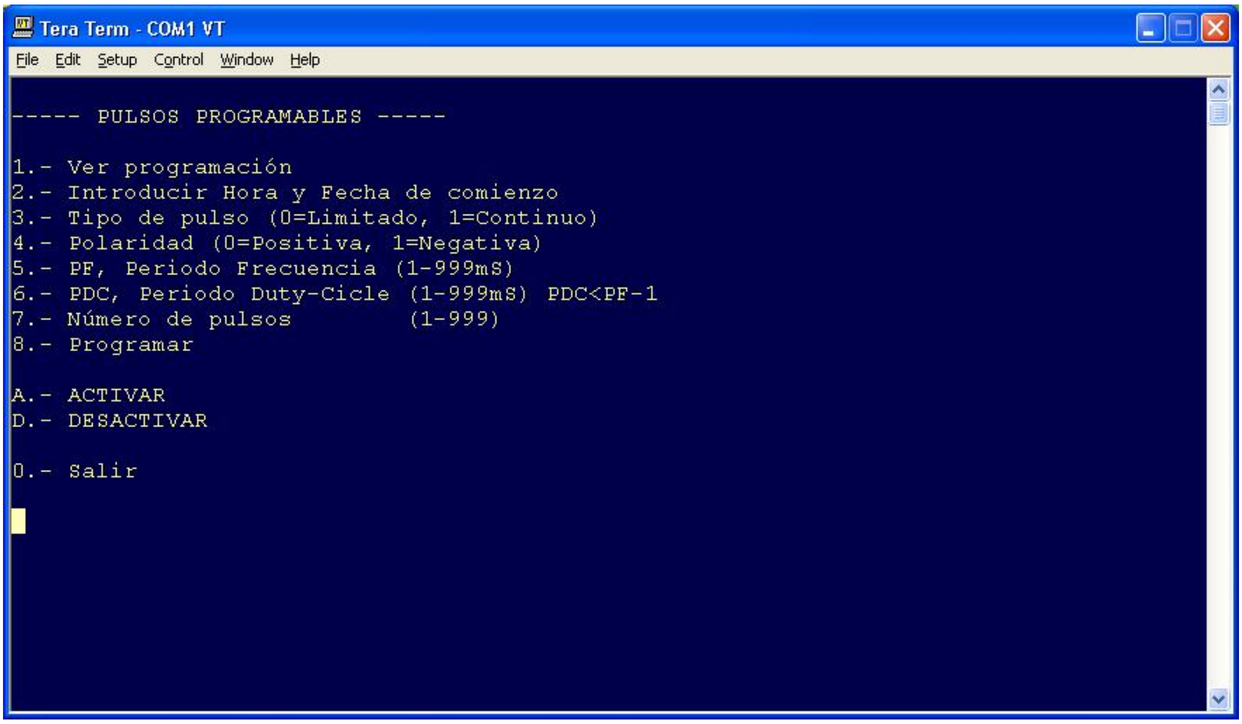
7.3.12 Reset

Con esta opción podemos hacer un RESET al equipo.



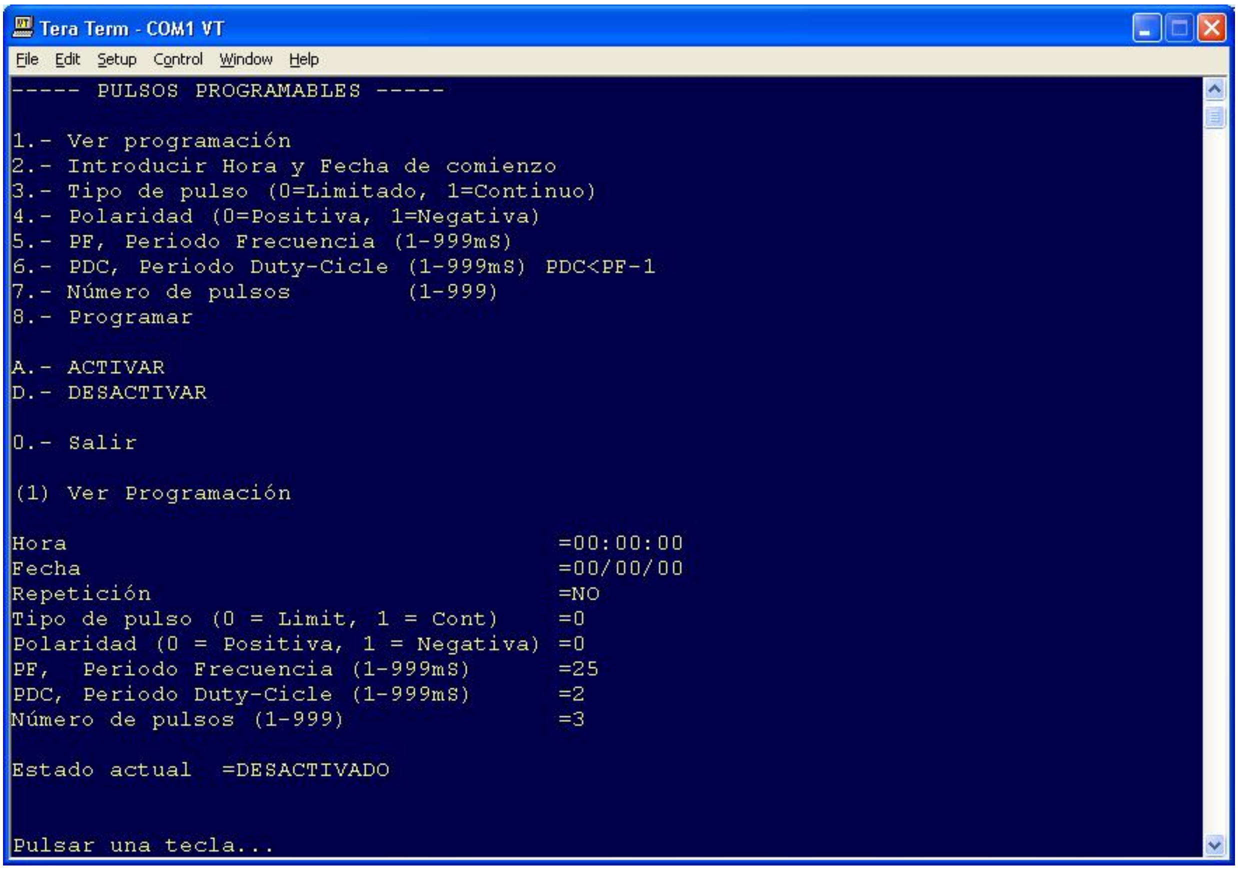
7.4 Configuración Pulsos Programables

Este menú permite configurar y visualizar los parámetros del Generador de Pulsos Programables.



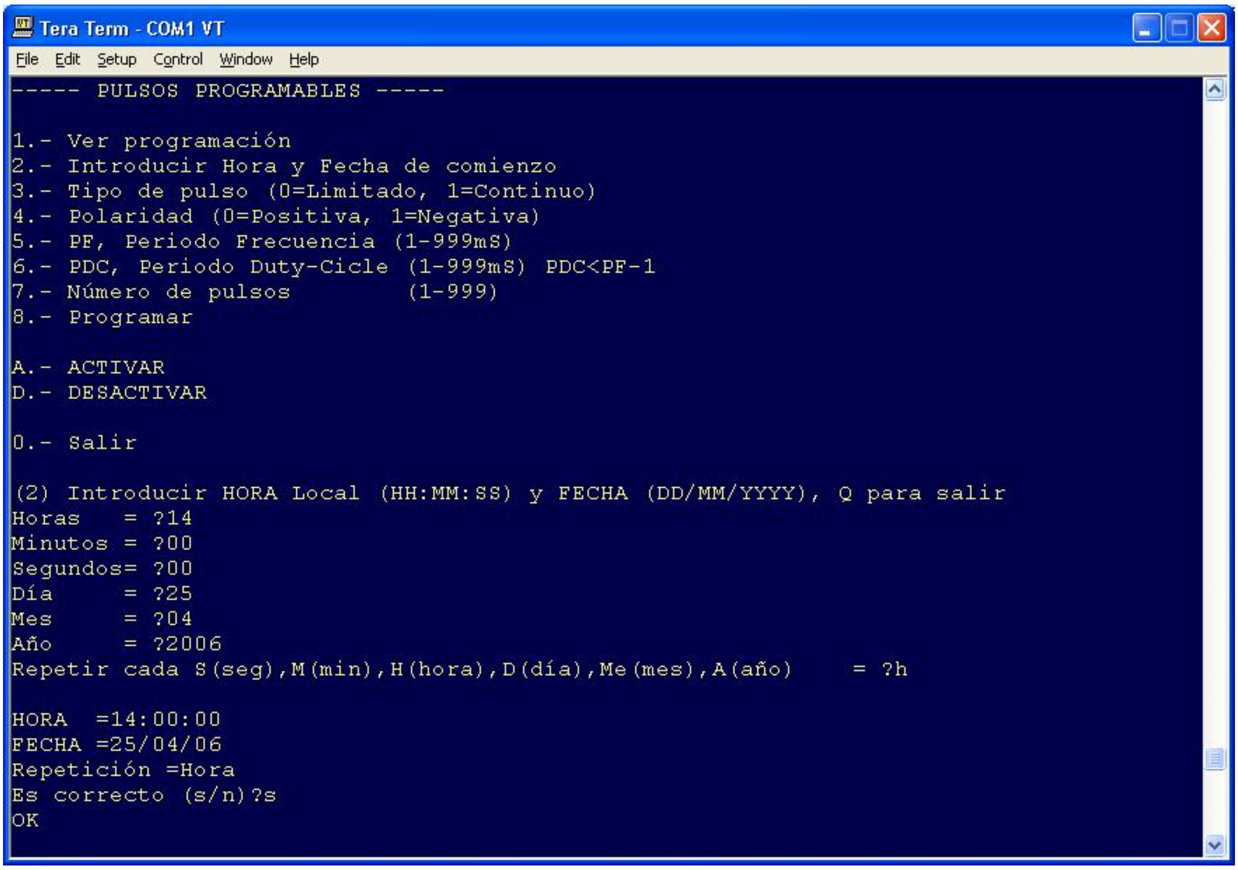
7.4.1 Ver programación actual

Mediante esta opción podemos ver el estado del generador PP, que por defecto no está programado.



7.4.2 Programación de comienzo

El primer paso para configurar el generador PP es programar la fecha y la hora de comienzo de los PP, dado que el generador es síncrono con el PPS, debemos prever que los PP no saldrán hasta que el reloj este de nuevo sincronizado con GPS, esto puede tardar hasta 150 segundos, por lo que si hemos programado una hora muy próxima a la actual podemos perder el momento de comienzo de los PP.



7.4.3 Tipo de Pulso

Este parámetro indica al generador de PP si ha de generar un tren de pulsos de n pulsos o si una vez arrancado el generador los pulsos saldrán indefinidamente.

Numero de pulsos limitado.

Numero de pulsos ilimitado.

Por defecto está programado 0

7.4.4 Polaridad del pulso

La polaridad de los pulsos indica cual es el flanco activo de los PP.

0- Polaridad positiva, el flanco activo es de flanco de subida.
1- Polaridad negativa, el flanco activo es de flanco de bajada.

Por defecto está programado 0

7.4.5 Periodo de la frecuencia

(PF) Indica al generador el periodo de la frecuencia de un pulso individual, es decir la suma en tiempo de la parte del pulso que está a nivel lógico 1 y la que está a nivel lógico 0.

El valor puede ir de 1 ms a 999 ms.

7.4.6 Periodo Duty-Cicle

(PDC) Indica al generador la anchura que debe tener el pulso.

Existe una limitación para este parámetro, que es el hecho de que PDC debe ser menor que PF, como es lógico.

El valor puede ir de 1 ms a 999 ms.

7.4.7 Número de pulsos

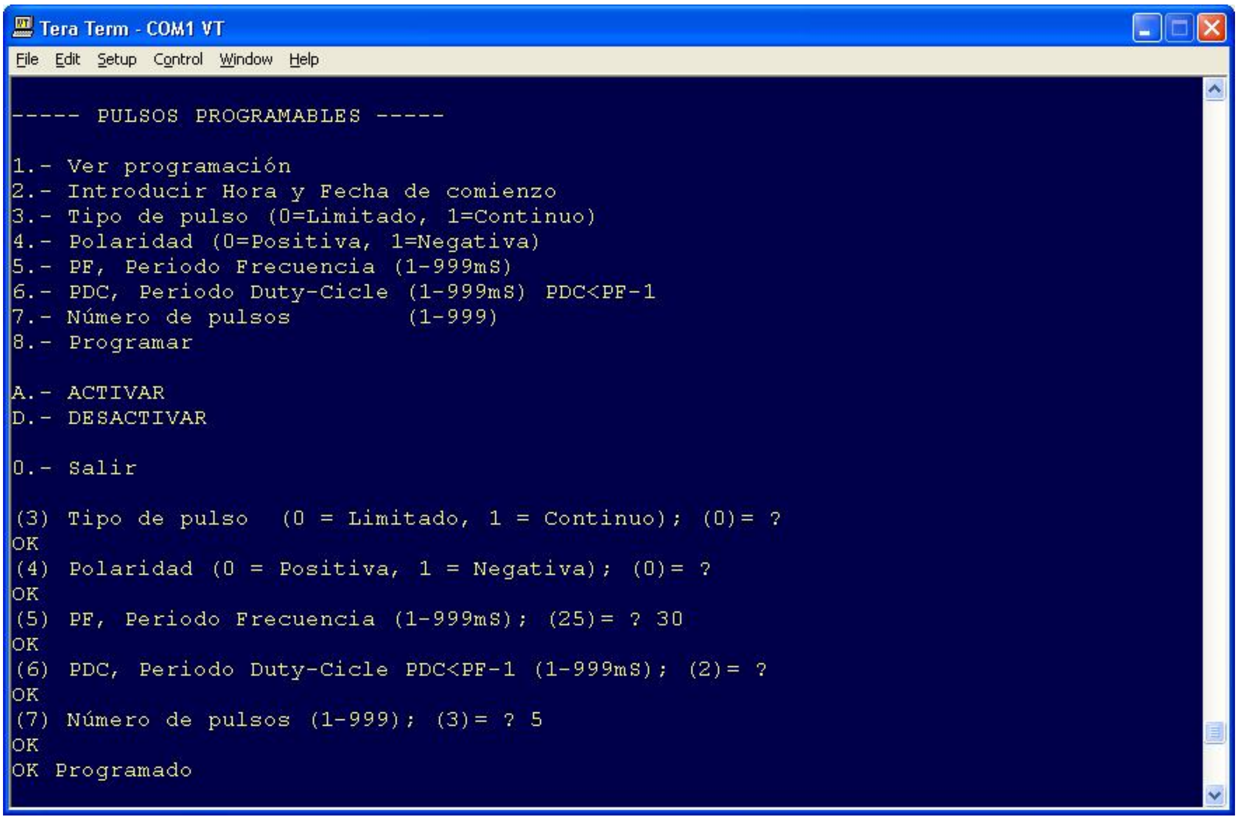
(NPP) Indica al generador el número de pulsos que ha de generar con las características antes programadas

El valor puede ir de 1 a 999.

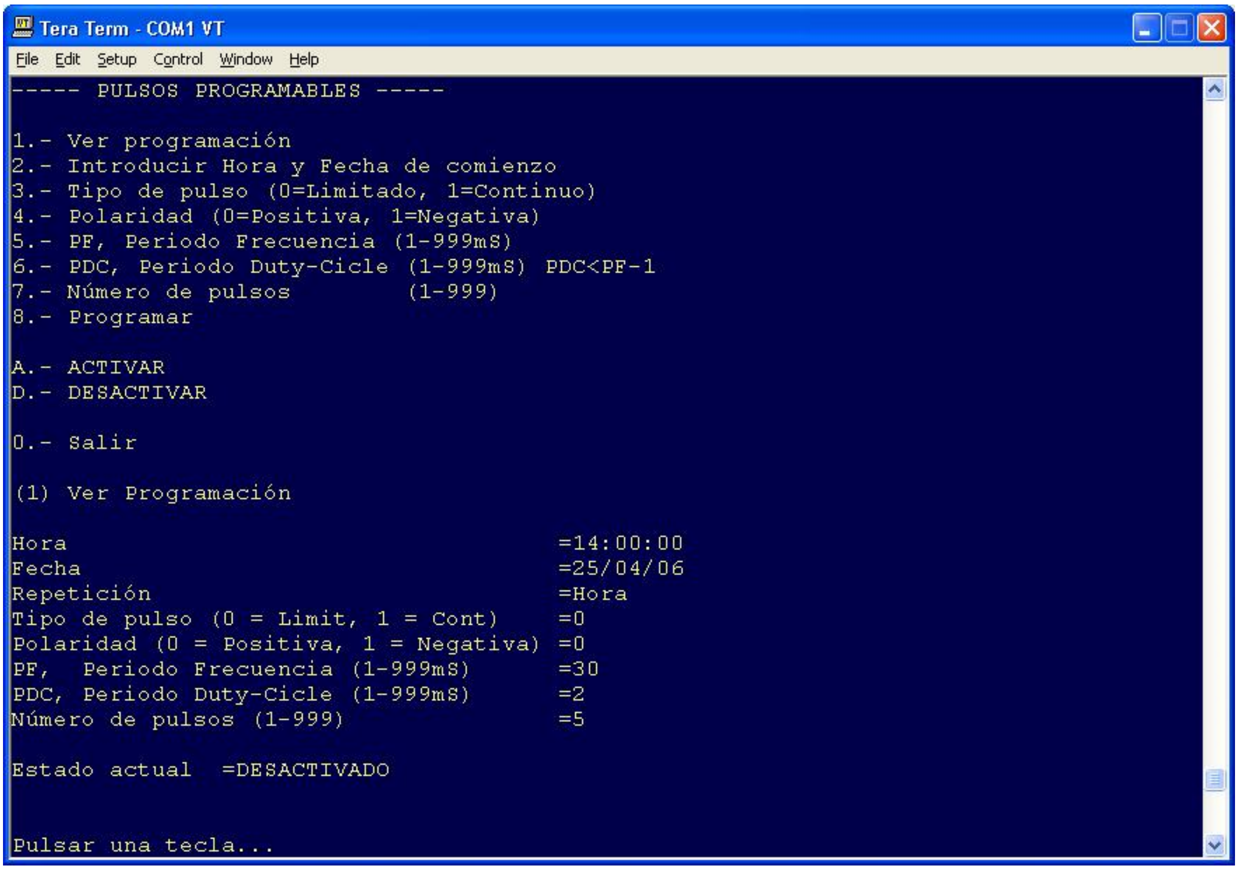
7.4.8 Programación

Una vez configurados los parámetros anteriores estos deben ser programados en el generador de PP, esta tarea se realiza mediante la función “8.- Programar.”

Desde este momento los parámetros programados pasan a ser valores por defecto para siguientes programaciones hasta que se apague el equipo.



Si queremos comprobar la programación que hemos introducido deberemos ir a la opción 1.



7.4.9 Activación y Desactivación

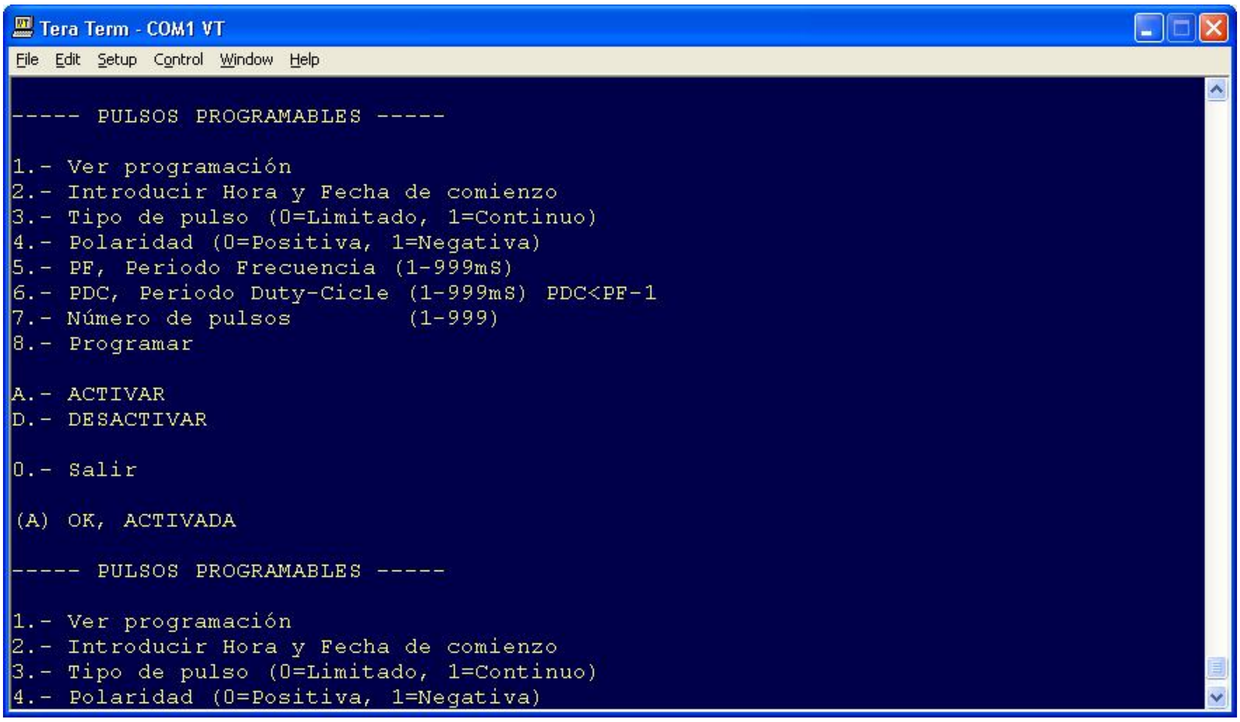
Ahora es necesario activar el generador de PP para que en el momento en el que la hora y la fecha programada sean iguales a las del reloj, se produzca el arranque el generador de PP.

Para ello es necesario elegir:

- Opción “A” y volver a MODO RELOJ.

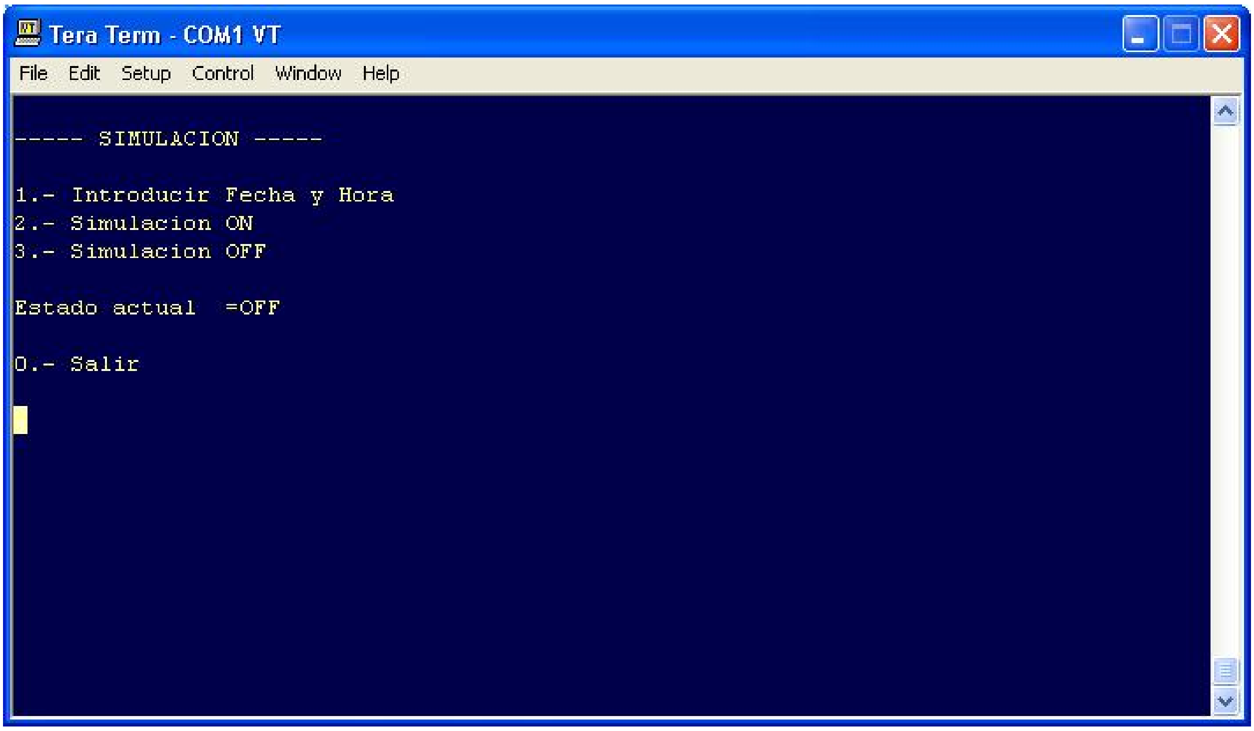
Si queremos detener el generador PP elegiremos la opción:

- Opción “D” y volver a MODO RELOJ.



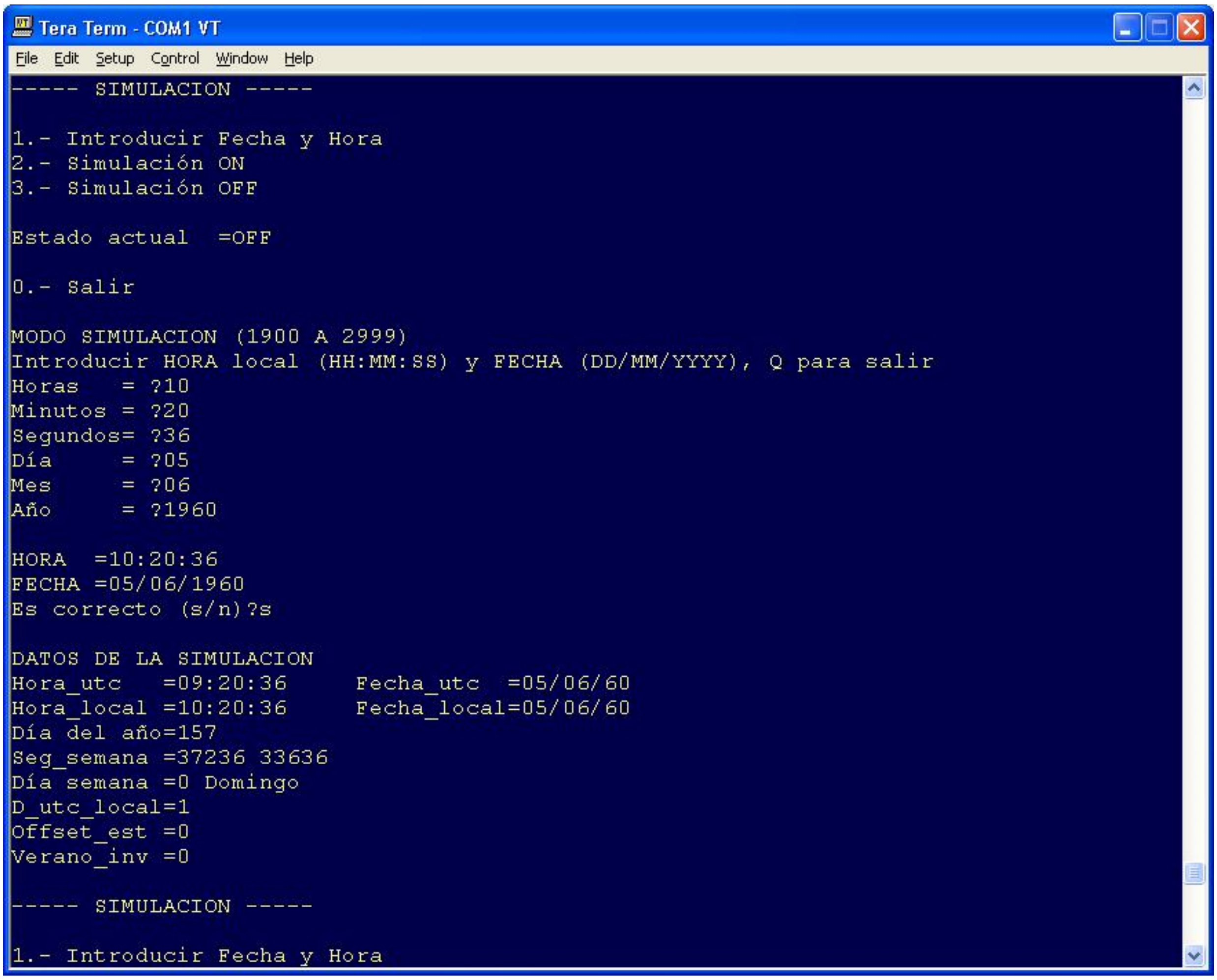
7.5 Simulación

Este menú permite configurar la función de simulación, con ella podremos programar el reloj para situarlo en una fecha y hora determinada del pasado o del futuro dentro del rango 1900 a 2999.

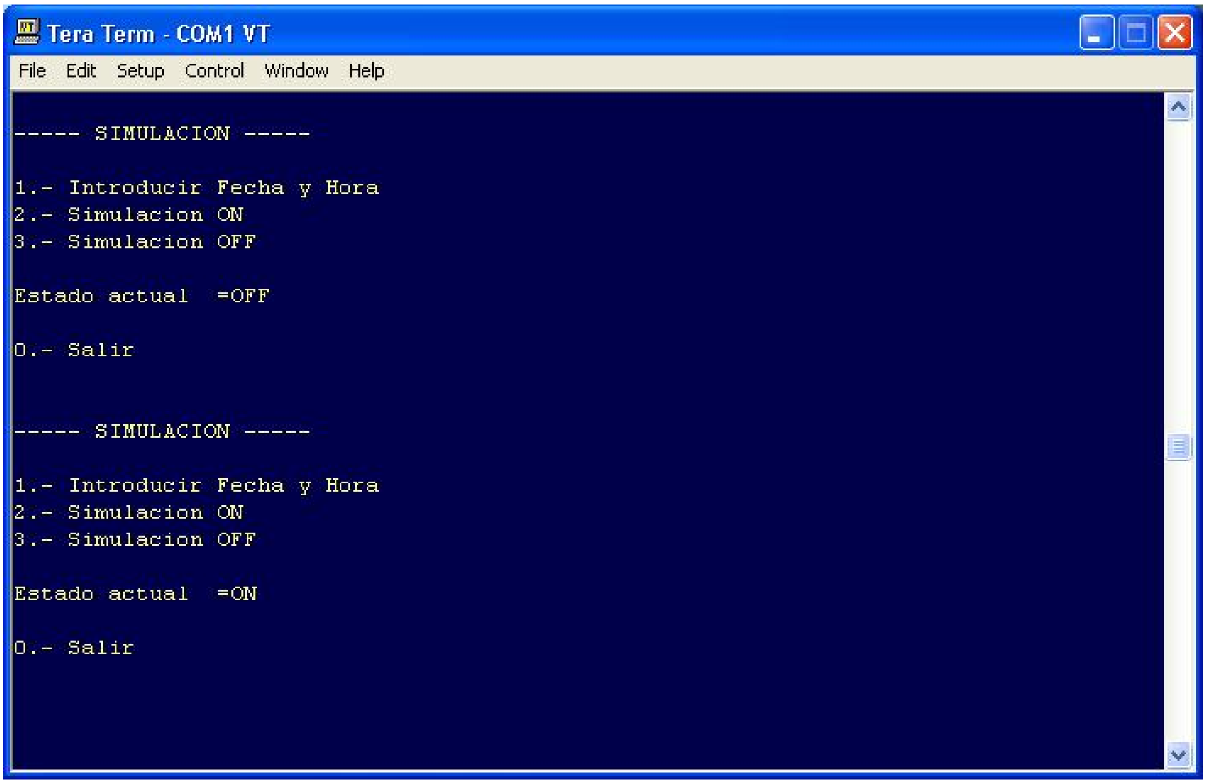


7.5.1 Fecha y hora de simulación

Desde esta opción programaremos la fecha y la hora deseada y el reloj nos informara de los diversos parámetros que intervienen en la simulación.



7.5.2 ON y OFF



Con estas opciones podemos activar y desactivar la simulación

8. Documentos de referencia

Electromagnetic Compatibility

Product Specific:	EN 50263:1999

Electromagnetic Compatibility Emissions

Product Specific:	IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	ENV 50141:1993
	IEC 60255-22-6:2001
Digital Radio Telephone RF Immunity:	ENV 50204:1995
Electrostatic Discharge Immunity:	IEC 60255-22-2:1996
	IEC 61000-4-2:1995
Fast Transient/Burst Immunity:	IEC 60255-22-4:2002
	IEC 61000-4-4:1995
Magnetic Field Immunity:	EN 61000-4-8:1993
Radiated Radio Frequency Immunity:	ENV 50140:1993
	IEC 60255-22-3:2000
	IEC 61000-4-3:1998

Environmental

Cold:	IEC 60068-2-1:1990
Dry Heat:	IEC 60068-2-2:1974
Damp Heat Cyclic:	IEC 60068-2-30:1980
Vibration:	IEC 60255-21-1:1988
	IEC 60255-21-2:1988
	IEC 60255-21-3:1993

Safety

Dielectric Strength:	IEC 60255-5:2000
	IEEE C37.90–1989
Impulse:	IEC 60255-5:2000
Product Safety:	IEC 61010-1:1990

9. Mantenimiento y garantía

El REAL-TIME GPS V02 tiene una garantía de 2 años contra todo defecto de fabricación desde la fecha de compra, esta garantía permite reparar o reemplazar las piezas o componentes defectuosos por el servicio postventa de TELECOCABLE.

Quedan fuera de garantía todo equipo que haya sido manipulado por personal ajeno a TELECOCABLE, así como aquellas piezas, componentes o equipos que hayan sido indebidamente instalados, manipulados o sometidos a condiciones fuera de las especificaciones.

TELECOCABLE no asume ninguna responsabilidad sobre cualquier daño causado a terceros.

10. Especificaciones

Precisión PPS

Mejor que +/- 50 nanosegundos con sincronización GPS

Precisión PP

Mejor que +/-100 nanosegundos con sincronización GPS

Precisión IRIGB003/4

Mejor que +/-100 nanosegundos con sincronización GPS

Precisión frecuencia 1Khz

Mejor que +/-100 nanosegundos con sincronización GPS

Precisión REE

Mejor que +/-1 microsegundo con sincronización GPS

Salidas TTL (IRIGB003/4, PPS, 1KHz, PP)

Conector BNC aislado.
Protección contra inversión de polaridad
Protección contra sobretensiones por encima de 5 Vdc.
Impedancia de salida de 50 ohm.

Salida FO (IRIGB003/4, PPS, PP, REE)

Conector ST
820 nm longitud de onda.
2500 metros de alcance.
Compatible con fibras multimodo 50/125 µm, 62.5/125 µm, 100/140 µm.

Salida RS485 (IRIGB003/4, REE)

Conector enchufable de tres vías.
Protección contar sobretensiones en modo común y modo diferencial con diodos supresores de transitorios y fusibles rearmables 100mA.

Aislamiento galvánico mediante optoacoplador rápido y convertidor DC/DC 1Kv
Alta velocidad 2.5 Mbps.
Posibilidad de resistencia terminadora de bus 120 ohm y pulldown pullup de 1Kohm.
Hasta 32 receptores.

Salidas RS232 (REE1 y REE2)

Conector Sub-D 9 Hembra
Protección contra sobretensiones con diodo supresor transitorios.
Aislamiento galvánico mediante optoacoplador rápido y convertidor DC/DC 1Kv
Velocidad 9600 bps, 7 bits de datos, 1 bit se stop y paridad par.

Salida IRIGB123/4 Modulada

Conector BNC aislado.
Frecuencia 1Khz
Modulación AM.
Relación de Modulación 3 a 1
Amplitud 5 Vpp.
Impedancia de salida de 50 ohm.

Entrada Antena

Conector BNCT
Impedancia de 75 ohm.

Entrada RS232 (MONITOR)

Conector Sub-D 9 Hembra
Protección contra sobretensiones con diodo supresor transitorios.
Aislamiento galvánico mediante optoacopladores y convertidor DC/DC 1Kv
Velocidad 9600 bps, 8 bits de datos, 1 bit se stop y sin paridad

Alimentación

Conector universal CA con filtro EMI

Opción 1, 48VCC:

Convertidor CC/CC 48 Vcc (36 a 75 Vcc).
Eficiencia del 84%
Potencia 10W (2 Amp a 5 Vdc)
Aislamiento entrada salida de 1.6Kv cc.
Protección contra cortocircuitos y sobretensiones.
Fusible de 500 mA.
Consumo inferior a 1.500 mA.

Opción 2, Multirango CA o CC:

Fuente conmutada multirango 84-264 V en CC o CA
Eficiencia del 82%
Potencia 10W (2 Amp a 5 Vdc)
Aislamiento entrada salida de 4242 Vcc.
Entrada con filtro EMI
Protección contra cortocircuitos y sobretensiones.
Fusible de 500 mA.
Consumo inferior a 1.500 mA.

Temperatura de operación

−10° a +80 °C

Humedad

0% a 95% sin condensación

Altitud

2000 m máx.

Peso

2.5 Kg.

Dimensiones

483mm x 44 mm x 252 mm

11. Anexos

Anexo I

Documentación IRIG

Range Commanders Council

TELECOMMUNICATIONS
AND TIMING GROUP

IRIG STANDARD 200-04

IRIG SERIAL TIME CODE FORMATS

WHITE SANDS MISSILE RANGE
REAGAN TEST SITE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
NATIONAL TRAINING CENTER
ELECTRONIC PROVING GROUND

NAVAL AIR WARFARE CENTER WEAPONS DIVISION
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY
NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT
NAVAL STRIKE AND AIR WARFARE CENTER

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
AIR WARFARE CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE
UTAH TEST AND TRAINING RANGE

NATIONAL NUCLEAR SECURITY ADMINISTRATION (NEVADA)

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IRIG SERIAL TIME CODE FORMATS

SEPTEMBER 2004

Prepared by

TIMING COMMITTEE
TELECOMMUNICATIONS AND TIMING GROUP
RANGE COMMANDERS COUNCIL

Published by

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New Mexico 88002-5110

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RANGE COMMANDERS WEBSITE AT
http://jcs.mil/RCC

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CHANGES TO THIS EDITION

IRIG Standard 200-98 was last updated in May 1998 and defined the characteristics of the serial time codes A, B, D, E, G, and H   This 2004 edition of the Standard incorporates year information for codes A, B, E, and G. Codes D and H remain unchanged. The task of revising this standard was assigned to the Telecommunications and Timing Group (TTG) of the Range Commanders Council (RCC).

All U.S. Government ranges and facilities should adhere to this standard where serial time codes are generated for correlation of data with time.

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ACRONYMS AND ABBREVIATIONS

ABBREVIATIONS (by category)	TERMS
CF	Control Function
Hz	An abbreviation for Hertz (Cycles per second)
k	1000
kHz	Kilohertz (1000 Hz)
fph	Frames per hour
fpm	Frames per minute
fps	Frames per second
pph	Pulses per hour
ppm	Pulses per minute
pps	Pulses per second
y	Year
mo	Month
d	Day
h	Hour
m	Minute
s	Second
ms	Millisecond (10^{-3}s)
µs	Microsecond (10^{-6}s)
ns	Nanosecond (10^{-9}s)
DoY	Day-of-year
DoM	Day-of-month
HoD	Hour-of-day
MoH	Minutes-of-hour
SoD	Seconds-of-day ($86.4x10^3$)
MoD	Milliseconds-of-day ($86.4x10^6$)
MioD	Microseconds-of-day ($86.4x10^9$)
BCD	Binary coded decimal
SBS	Straight binary second(s)
SB	Straight binary
BIT	B(INARY + DIG)IT
LSB	Least significant bit
MSB	Most significant bit
NRZ-L	Non return to zero level
SBS	Straight binary time of day (seconds of day)
SB	Straight binary

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CHAPTER 1

INTRODUCTION

Modern day electronic systems such as communication systems, data handling systems, and missile and spacecraft tracking systems require time-of-day and year information for correlation of data with time. Parallel and serial formatted time codes are used to efficiently interface the timing system output with the user system. Parallel time codes are defined in IRIG Standard 205-87, IRIG Standard Parallel Binary and Parallel Binary Coded Decimal Time Code Formats. Standardization of time codes is necessary to ensure system compatibility among the various ranges, ground tracking networks, spacecraft and missile projects, data reduction facilities, and international cooperative projects.

This standard defines the characteristics of six serial time codes presently used by the U.S. Government and private industry. Year information has been added to IRIG codes A, B, E, and G. It should be noted that this standard reflects the present state-of-the-art in serial time code formatting and is not intended to constrain proposals for new serial time codes with greater resolution.

All Department of Defense (DoD) test ranges, facilities, and other government agencies such as the National Aeronautics and Space Administration (NASA) maintain Coordinated Universal Time (UTC) referenced to the United States Naval Observatory (USNO) Master Clock. The designation for time in the United States is UTC (USNO).

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CHAPTER 2

GENERAL DESCRIPTION OF THIS STANDARD

This standard consists of a family of rate-scaled serial time codes with formats containing up to four coded expressions or words. All time codes contain control functions that are reserved for encoding various controls, identification, and other special purpose functions. Time codes A, B, D, E, G, and H are described below.

- Time code A has a time frame of 0.1 seconds with an index count of 1 millisecond and contains time-of-year and year information in a binary coded decimal (BCD) format, and seconds-of-day in straight binary seconds (SBS).

- Time code B has a time frame of 1 second with an index count of 10 milliseconds and contains time-of-year and year information in a BCD format, and seconds-of-day in SBS.

- Time code D has a time frame of 1 hour with an index count of 1 minute and contains time-of- year information in days and hours in a BCD format.

- Time code E has a time frame of 10 seconds with an index count of 100 milliseconds and contains time-of-year and year information in a BCD format.

- Time code G has a time frame of 0.01 seconds with an index count of 0.1 milliseconds and contains time-of year information in days, hours, minutes, seconds, fractions of seconds and year information in a BCD format.

- Time code H has a time frame of 1 minute with an index count of 1 second and contains time-of-year information in days, hours, and minutes in a binary coded decimal BCD format.

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CHAPTER 3

GENERAL DESCRIPTION OF FORMATS

3.1 Overview

A description of the time code formats is described in the subparagraphs below. Additional reference information is provided at the end of this document on the related topics of leap year and leap second conventions (Appendix A), Binary Coded Decimal (BCD) count data and binary count data (Appendix B), and time code generator hardware design considerations (Appendix C).

3.2 Time Code Formats

3.2.1 Pulse Rise Time. The specified pulse (dc level shift bit) rise time shall be obtained between the 10 and 90 percent amplitude points (see Appendix C).

3.2.2 Jitter. The modulated code is defined as $\leq$ 1 percent at the carrier frequency. The dc level shift code is defined as the pulse-to-pulse variation at the 50 percent amplitude points on the leading edges of successive pulses or bits (see Appendix C).

3.2.3 Bit Rates and Index Count. Each pulse in a time code word/sub-word is called a bit. The "on-time" reference point for all bits is the leading edge of the bit. The repetition rate at which the bits occur is called the bit rate. Each bit has an associated numerical index count identification. The time interval between the leading edge of two consecutive bits is the index count interval. The index count begins at the frame reference point with index count 0 and increases one count each index count until the time frame is complete.

The bit rates and index count intervals of the time code formats are shown in Table 3-1.

TABLE 3-1. BIT RATES AND INDEX COUNT INTERVALS OF THE TIME CODE FORMATS

Format	Bit Rate[1]	Index Count Interval
A	1 kpps	1 millisecond
B	100 pps	10 milliseconds
D	1 ppm	1 minute
E	10 pps	0.1 second
G	10 kpps	0.1 millisecond
H	1 pps	1 second

[1] See the abbreviations and acronyms page at the beginning of this document for bit rate definitions

3.2.4 Time Frame, Time Frame Reference, and Time Frame Rates. A time code frame begins with a frame reference marker P_0 (position identifier) followed by a reference bit P_r with each having duration equal to 0.8 of the index count interval of the respective code. The on-time reference point of a time frame is the leading edge of the reference bit P_r. The repetition rate at which the time frames occur is called the time frame rate. The time frame rates and time frame intervals of the formats are shown in Table 3-2.

TABLE 3-2. TIME FRAME RATES AND TIME FRAME INTERVALS OF THE FORMATS

Format	Time Frame Rate	Time Frame Interval
A	10 fps	0.1 second
B	1 fps	1 second
D	1 fph	1 hour
E	6 fpm	10 seconds
G	100 fps	10 ms
H	1 fpm	1 minute

3.2.5 Position Identifiers. Position identifiers have durations equal to 0.8 of the index count interval of the respective code. The leading edge of the position identifier P_0 occurs one index count interval before the frame reference point P_r and the succeeding position identifiers (P_2, P_2...P_0) occur every succeeding tenth bit. The repetition rate at which the position identifiers occur is always 0.1 of the time format bit rate.

3.2.6 Time Code Words. The two time code words employed in this standard are:

- Binary Coded Decimal (BCD) time-of-year and year
- Straight Binary Seconds (SBS) time-of-day (seconds-of-day)

All time code formats are pulse-width coded. A binary (1) bit has duration equal to 0.5 of the index count interval, and a binary (0) bit has duration equal to 0.2 of the index count interval. The BCD time-of-year code reads 0 hours, minutes, seconds, and fraction of seconds at 2400 each day and reads day 001 at 2400 of day 365 or day 366 in a leap year. The year code counts year and cycles to the next year on January 1st of each year and will count to year 2099. The SBS time-of-day code reads 0 seconds at 2400 each day excluding leap second days when a second may be added or subtracted.

3.2.7 BCD Time-of-Year Code Word. The BCD time-of-year and year code word consists of sub-words in days, hours, minutes, seconds, and year with fractions of a second in a BCD representation and time-of-day in SBS of day. The position identifiers preceding the decimal digits and the index count locations of the decimal digits (if present) are in Table 3-3.

Formats A and B include an optional SBS time code word in addition to a BCD time-of-year time and year code word. The SBS word follows position identifier P_8 beginning with the least significant binary bit (2^0) at index count 80 and progressing to the most significant binary bit (2^{16}) at index count 97 with a position identifier P_9 occurring between the ninth (2^8) and tenth (2^9) binary bits. Codes A, B, E, and G also contain year information in a BCD format and are an extension to the time-of-year format.

TABLE 3-3. POSITION IDENTIFIERS AND INDEX COUNT LOCATIONS		
BCD Code Decimal Digits	**Decimal Digits Follow Position Identifier**	**Digits Occupy Index Count Positions**
Units of seconds Tens of Seconds	P_0	1-4 6-8
Units of Minutes Tens of Minutes	P_1	10-13 15-17
Units of Hours Tens of Hours	P_2	20-23 25-26
Units of Days Tens of Days	P_3	30-33 35-38
Hundreds of Days Tenths of Seconds	P_4	40-41 45-48
Hundredths of Seconds	P_5	50-53
For Codes A, B, and E Tens of Years Hundredths of Years	P_5	 51-54 56-59
For Code G Tens of Year Hundredths of Year	P_6	 61-64 66-69

3.2.8 Control Functions. All time code formats reserve a set of bits known as control functions (CF) for the encoding of various control, identification, and other special purpose functions. The control bits may be programmed in any predetermined coding system. A binary 1 bit has duration equal to 0.5 of the index count interval, and a binary (0) bit has duration equal to 0.2 of the index count interval. Control function bits follow position identifiers P_5, P_6 or P_7 for formats A, B, E, and G beginning at index count 50, 60 or 70 with one control function bit per index count, except for each tenth bit which is a position identifier. The number of available control bits in each time code format is shown at Table 3-4.

TABLE 3-4. NUMBER OF AVAILABLE CONTROL BITS IN EACH TIME CODE FORMAT	
Format	**Control Functions**
A	18
B	18
D	9
E	36
G	27
H	9

Control functions are presently intended for internal range use, but not for interrange applications; therefore, no standard coding system exists. The inclusion of control functions into a time code format as well as the coding system employed is an individual user defined option.

3.2.9 Index Markers. Index markers occur at each index count position, which is not assigned as a reference marker, position identifier, code, or control function bit. Each index marker bit has duration equal to 0.2 of the index count interval of the respective time code format.

3.2.10 Amplitude Modulated Carrier. A standard sine wave carrier frequency to be amplitude modulated by a time code is synchronized to have positive-going, zero-axis crossings coincident with the leading edges of the modulating code bits. A mark-to-space ratio of 10:3 is standard with a range of 3:1 to 6:1 (see Typical Modulated Carrier Signal descriptions at Figure 3-1 and Table 3-5).

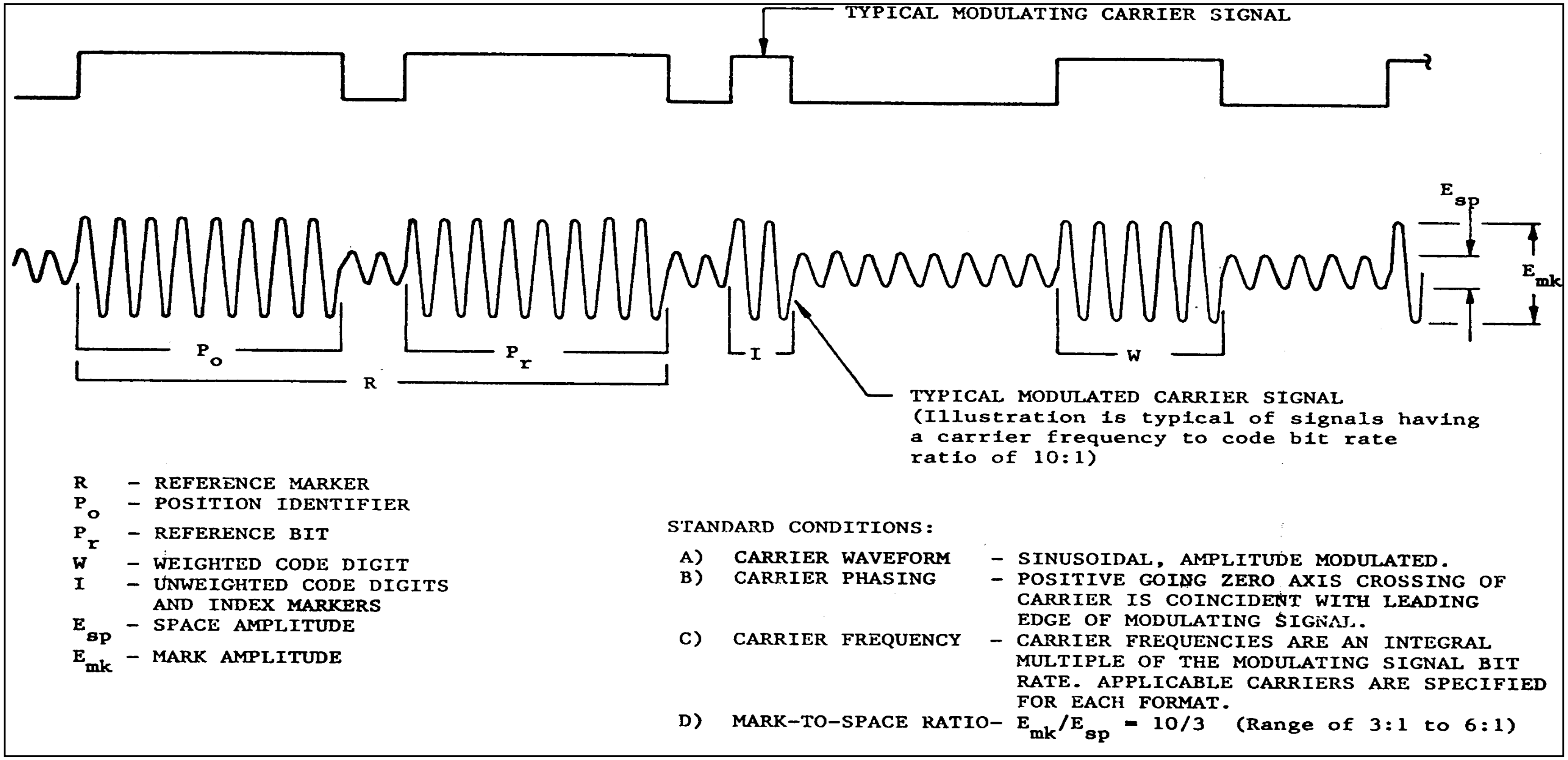

Figure 3-1. Typical modulated carrier signal.

TABLE 3-5. TYPICAL MODULATED CARRIER SIGNAL FORMATS FOR A, B, E, D, G, AND H								
FORMATS					**MARK INTERVAL NUMBER OF CYCLES**			
FORMAT	SIGNAL NO.	TIME FRAME RATE	CARRIER FREQUENCY F	SIGNAL BIT RATE ER	RATIO F/ER	CODE "0" & INDEX	CODE "1"	POSITION IDENTIFIER & REF.
A	A130, 132 133, 134	10 per sec.	10 kHz	1 kpps	10:1	2	5	8
B	B120, 122 123, 127	1 per sec.	1 kHz	100 pps	10:1	2	5	8
D	D111, 112 121,122	1 per hr.	100Hz 1kHz	1 ppm 1 ppm	6000:1 60000:1	1200 12000	3000 30000	4800 48000
E	E111, 112 121,122, 125	6 per min	100Hz 1kHz	10 pps 10 pps	10:1 100:1	2 20	5 50	8 80
G	G141, 142, 126	100 per sec.	100 kHz	10 kpps	10:1	2	5	8
H	H111, 112 121,122	1 per min.	100 Hz 1 kHz	1 pps 1 pps	100:1 1000:1	20 200	50 500	80 800

CHAPTER 4

DETAILED DESCRIPTION OF FORMATS

4.1 Time Code Formats (A, B, D, E, and G)

4.1.1 Serial Time Code Formats. The family of rate-scaled serial time code formats is designated A, B, D, E, G, and H. Various combinations of sub-words and signal forms make up a time code word. All formats do not contain each standard coded expression, and various signal forms are possible. To differentiate between these forms, signal identification numbers are assigned to each permissible combination (see Figure 4-1).

Format:

Format A	1 k pps
Format B	100 pps
Format D	1 ppm
Format E	10 pps
Format G	10 k pps
Format H	1 pps

Modulation Frequency:

0	Pulse width code
1	Sine wave, amplitude modulated
2	Manchester modulated

Frequency/Resolution:

0	No carrier/index count interval
1	100 Hz/10 ms
2	1 kHz/1 ms
3	10 kHz/0.1 ms
4	100 kHz/10 ms
5	1 MHz/1ms

Coded Expressions:

0	BCD_{TOY}, CF, SBS
1	BCD_{TOY}, CF
2	BCD_{TOY}
3	$BCD_{TOY,}$ SBS
4	$BCD_{TOY,}$ $BCD_{YEAR,}$ CF, SBS
5	$BCD_{TOY,}$ BCD_{YEAR}, CF
6	BCD_{TOY}, BCD_{YEAR}
7	BCD_{TOY}, BCD_{YEAR}, SBS

A 1 3 7

The signal designated as A137 is deciphered as follows: Format A, Sine wave (amplitude modulated), 10 kHz carrier/0.1 ms resolution, and Coded expressions BCD_{TOY}, BCD_{YEAR}, and SBS.

Figure 4-1. Serial time code formats

4.1.2 Manchester Time Code Formats. The resolution of a time code is that of the smallest increment of time or the least significant bit that can be defined by a time code word or sub-word. The accuracy of a modified, Manchester time code can be determined by the rise-time of the on-time pulse in the Manchester code which marks the beginning of the on-time one-pulse-per-second as shown in Figure 3-1 above. The accuracy can range from milliseconds to nanoseconds or better depending on equipment and measurement technique. For the case of the unmodulated Manchester codes, the Position Marker PO, which marks the beginning of the second, can be used.

The information in Table 4-1 shows the permissible code formats. Codes D, and H remain unchanged. Codes A, B, E and G have changed to permit year information as indicated below. No other combinations are standard.

TABLE 4-1. PERMISSIBLE CODE FORMATS (A, B, D, E, G, H)

Format	Modulation Frequency	Frequency/ Resolution	Coded Expressions
A	0, 1, 2	0, 3, 4, 5	0, 1, 2, 3, 4, 5, 6, 7
B	0, 1, 2	0, 2, 3, 4, 5	0, 1, 2, 3, 4, 5, 6, 7
D	0, 1	0, 1, 2	1, 2
E	0, 1	0, 1, 2	1, 2, 5, 6
G	0, 1, 2	0, 4, 5	1, 2, 5, 6
H	0, 1	0, 1, 2	1, 2

The Telecommunications and Timing Group (TTG) of the Range Commanders Council (RCC) has adopted a Modified Manchester modulation technique as an option for the IRIG serial time codes A, B, and G as an addition to the standard AM modulation and level shift modulation now permitted. Also, year information has been added to codes A, B, E, and G. Codes D and H remain unchanged. It should be noted that at present, the assignment of control bits (control functions) to specific functions in the IRIG serial time codes is left to the end-user of the time codes.

4.2 Examples Of Typical Modulated Carrier Signal Formats For IRIG A, B, E, and G

Examples are provided on the following pages as follows:

IRIG A: Table 4-2
IRIG B Table 4-3
IRIG E Table 4-4
IRIG G Table 4-5

TABLE 4-2. TYPICAL MODULATED CARRIER SIGNAL FORMATS (IRIG A)	
Modified Manchester Modulations[1]	
A 237	2 = Manchester modulation 3 = 10 kHz/0.1 ms 7 = BCD_{TOY}, BCD_{YEAR}, SBS
Standard AM modulations (Example Formats)	
A130	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1 ms 0 = BCD_{TOY}, CF, SBS
A 134	1 = Sine wave, amplitude modulated 3 = 10 Khz/0.1 ms 4 = BCD_{TOY}, BCD_{YEAR}, CF, SBS
A 132	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1 ms 2 = BCD_{TOY}
A 136	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1 ms 6 = BCD_{TOY}, BCD_{YEAR}
A 133	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1 ms 3 = BCD_{TOY}, SBS
A 137	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1ms 7 = BCD_{TOY}, BCD_{YEAR}, SBS
A 131	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1ms 1 = BCD_{TOY}, CF
A 135	1 = Sine wave, amplitude modulated 3 = 10 kHz/0.1 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF

[1]Modified Manchester modulation is an option for IRIG A in addition to the standard AM modulation in the formats in this table

TABLE 4-3. TYPICAL MODULATED CARRIER SIGNAL FORMATS (IRIG B)	
Modified Manchester Modulations[1]	
B 237	2 = Manchester modulation 3 = 10 kHz/0.1 ms 7 = BCD_{TOY}, BCD_{YEAR}, SBS
Standard AM modulations (Example Formats)	
B120	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 0 = BCD_{TOY}, CF, SBS
B 124	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 4 = BCD_{TOY}, BCD_{YEAR}, CF, SBS
B 121	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 1 = BCD_{TOY}, CF
B 125	1 = Sine wave. Amplitude modulated 2 = 1 kHz/1 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF
B 122	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 2 = BCD_{TOY}
B 126	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 6 = BCD_{TOY}, BCD_{YEAR}
B 123	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 3 = BCD_{TOY} SBS
B 127	1 = Sine wave, amplitude modulated 2 = 1 kHz/1 ms 7 = BCD_{TOY}, BCD_{YEAR}, SBS
[1]Modified Manchester modulation is an option for IRIG B in addition to the standard AM modulation in the formats in this table.	

TABLE 4-4. TYPICAL MODULATED CARRIER SIGNAL FORMATS (IRIG E)	
Standard AM modulations (Example Formats)	
E 111	1 = Sine wave, amplitude modulated 1 = 100 Hz/10 ms 1 = BCD_{TOY}, CF
E115	1 = Sine wave, amplitude modulated 1 = 100 Hz/10 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF
E 112	1 = Sine wave, amplitude modulated 1 = 100 Hz/10 ms 2 = BCD_{TOY},
E 116	1 = Sine wave, amplitude modulated 1 = 100 Hz/10 ms 6 = BCD_{TOY}, BCD_{YEAR}
E 121	1 = Sine wave, amplitude modulated 2 = 1kHz/1 ms 1 = BCD_{TOY}, CF
E 125	1 = Sine wave, amplitude modulated 2 = 1kHz/1 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF
E 122	1 = Sine wave, amplitude modulated 2 = 1kHz/1 ms 2 = BCD_{TOY}
E 126	1 = Sine wave, amplitude modulated 2 = 1kHz/1ms 6 = BCD_{TOY}, BCD_{YEAR}

TABLE 4-5. TYPICAL MODULATED CARRIER SIGNAL FORMATS (IRIG G)	
Modified Manchester Modulations[1]	
G 245	2 = Manchester modulation 4 = 100 kHz/10 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF
Standard AM modulations (Example Formats)	
G 141	1 = Sign wave, amplitude modulation 4 = 100 kHz/10 ms 1 = BCD_{TOY}, CF
G 145	1 = Sign wave, amplitude modulation 4 = 100 kHz/10 ms 5 = BCD_{TOY}, BCD_{YEAR}, CF
G 142	1 = Sign wave, amplitude modulated 4 = 100 kHz/10 ms 2 = BCD_{TOY}
G 146	1 = Sign wave, amplitude modulated 4 = 100 kHz/10 ms 6 = BCD_{TOY}, BCD_{YEAR}
[1]Modified Manchester modulation is an option for IRIG G in addition to the standard AM modulation in the formats in this table	

4.3 Manchester II Coding

Standard Manchester modulation or encoding is a return-to-zero type, where a rising edge in the middle of the clock window indicates a binary one (1) and a falling edge indicates a binary zero (0). This modification to the Manchester code shifts the data window so the data are at the edge of the clock window that is on time with the one-pulse-per-second clock synchronized to Coordinated Universal Time (UTC). Thus, the data edge is the on-time mark in the code. Because this code is easy to generate digitally, easy to modulate onto fiber or coaxial cable, simple to decode, and has a zero mean, and the code is easy to detect even at low voltage levels.

The basic Modified Manchester modulation, compared with the AM and level shift modulations are shown at Figure 4-2 and Figure 4-3. The Manchester encoding uses a square-wave as the encoding (data) clock, with the rising edge on time with UTC. The frequency of the encoding clock shall be ten times the index rate of the time code generated. As an example, the clock rate for IRIG B230 shall be 10 kHz.

The Modified Manchester coding technique has several advantages as noted below.

- No dc component
- Can be ac coupled
- Better signal-to-noise ratio
- Good spectral power density
- Easily decoded
- Better timing resolution
- The link integrity monitoring capability is intrinsic to bipolar pulse modulation.
- The coding technique is designed to operate over fiber-optic or coaxial lines for short distances.

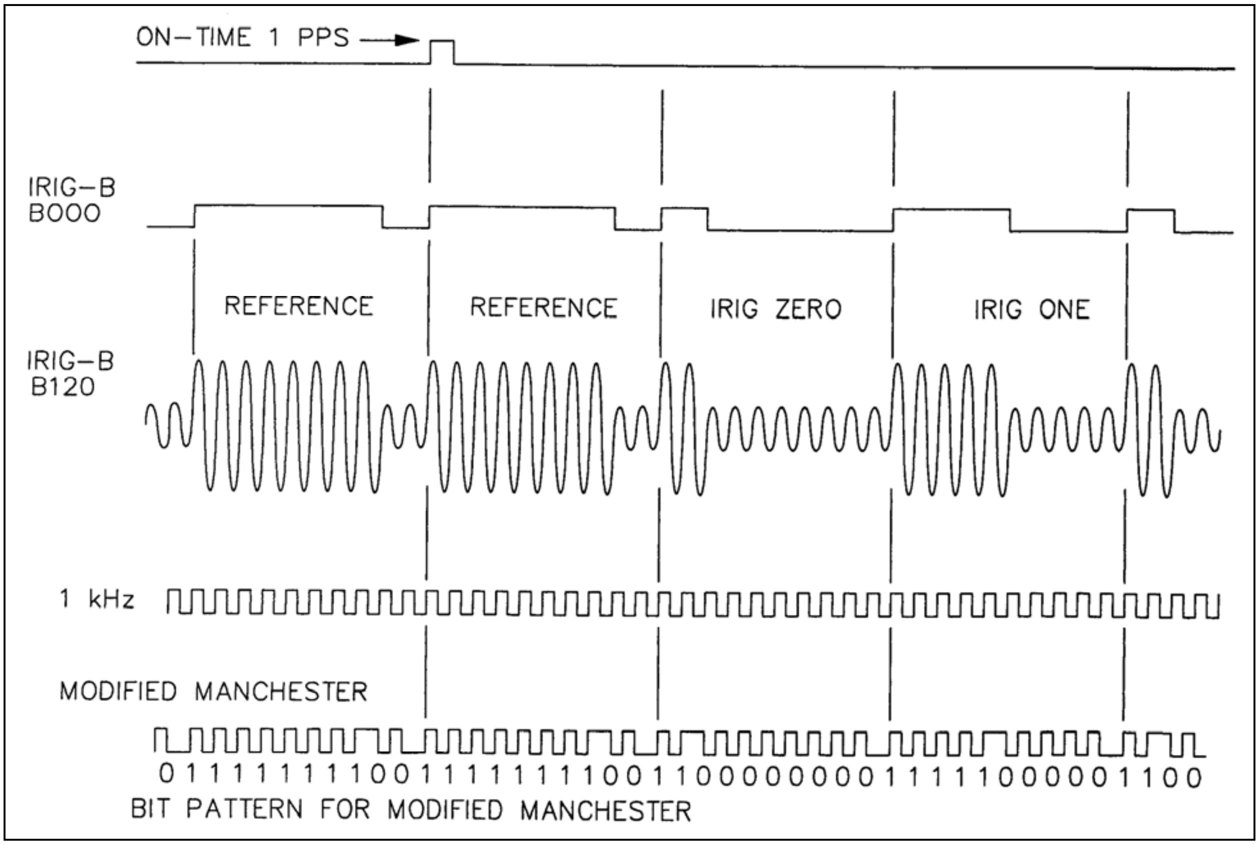

Figure 4-2. IRIG B coding comparisons: level shift, 1kHz am, and Modified Manchester.

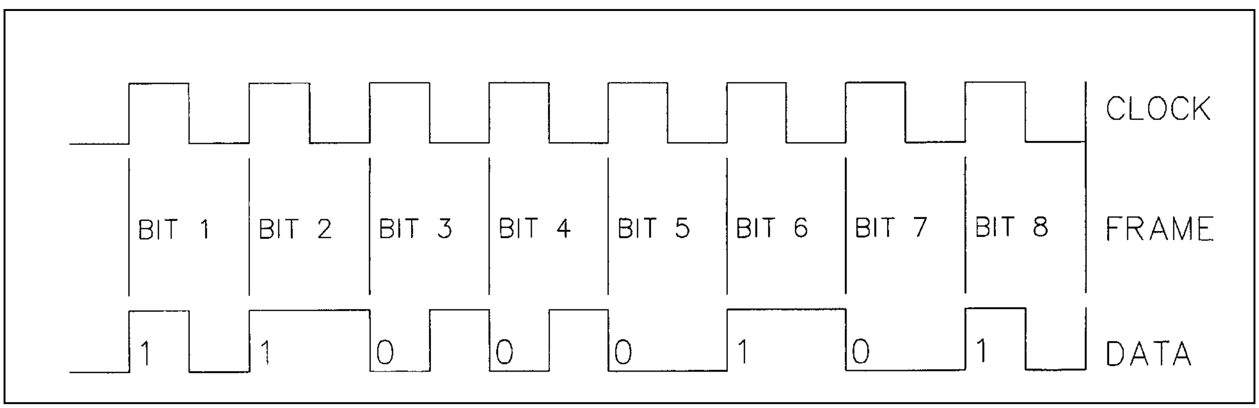

Figure 4-3. Modified Manchester coding.

4.4 Manchester II Decoding

An example of a Manchester II encoded sequence is shown at Figure 4-4, where each symbol is "sub-bit" encoded, i.e., a data one equals a zero-one, and a data zero equals a one-zero:

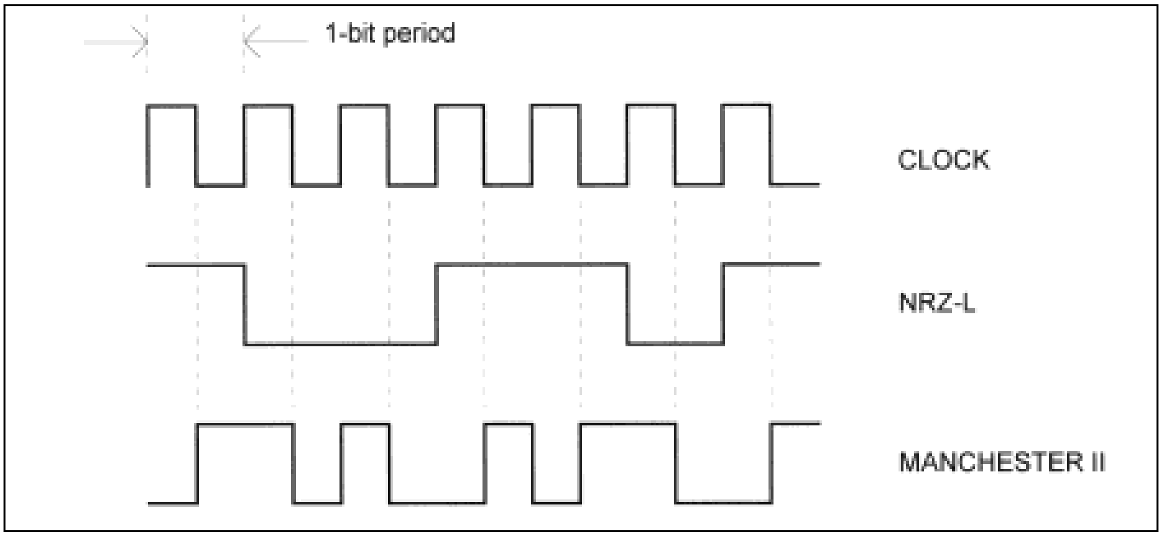

Figure 4-4. A Manchester II Encoded Sequence

The encoded sequence at Figure 4-4 is formed by modulo-2 adding the NRZ-L sequence with the clock. The truth table shown in Table 4-6 is for a modulo-2 adder, which is equivalent to an Exclusive-OR (XOR).

TABLE 4-6: TRUTH TABLE IS A MODULO-2 ADDER

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	0

To decode the encoded sequence of Figure 4-4, it is only necessary to modulo-2 add the clock with the encoded sequence and the original NRZ-L sequence results. It should be noted that the bit determination is made after integrating across a bit period. In this way, the maximum amount of bit energy is used in the determination of each bit. Likewise, one could have integrated or sampled both halves of the encoded sequence and reconstructed the original Non Return To Zero Level (NRZ-L) sequence by applying the encoding rule. This means that if sampled halves are 0-1, then a data 1 is reconstructed, and if the sampled halves are 1-0, then a data 0 is reconstructed. Once again, as much energy as possible is used from the encoded sequence to reconstruct the original NRZ-L sequence. This procedure minimizes the probability of error.

NOTE

When the above procedure is used, the reconstructed data are coherent with the clock; that is, the NRZ-L data transitions will agree with the positive going edge of the clock. However, since the decisions are made at the end of the symbol period, the reconstructed NRZ-L data are delayed one clock period; this means that when the entire time is received, the received time code or local clock needs to be advanced by one clock period. Also, if desired, one can correct the receive clock for significant signal propagation delays.

CHAPTER 5

GENERAL DESCRIPTION OF TIME CODES

5.1 Introduction

A general description of individual time code formats is described in the following sub-paragraphs. Year information has been added to formats A, B, E and G in 1, 2, 4, 8 and 10, 20, 40, 80 BCD bits using the unassigned Control Function (CF) BITs. This permits a year count from 2000 to 2099. If users desire the "Century Year" information, they can use two binary coded decimal BCD CF bits with a value of 0, 2, and 3. Therefore, a user wanting to start with year 2000 can count to year 2399.

5.2 Time Code Format A

5.2.1 The 78-bit time code contains 34 bits of BCD time-of-year information in days, hours, minutes and tenths of seconds, 17 bits of straight binary seconds-of-day (SBS), and 9 bits for year information in BCD. The remaining 18 bits are for control functions.

5.2.2 The BCD code (seconds sub-word) begins at index count 1 (LSB first) with binary coded bits occurring between position identifier P_0 and P_5. There are 7 bits for seconds, 7 for minutes, 6 for hours, 10 for days, 4 for tenths of seconds, and 9 for year information between position identifiers P_5 and P_6 to complete the BCD word. An index marker occurs between the decimal digits in each sub-word, except for the tenths of seconds, to provide for visual separation. The BCD time-of-year code recycles yearly.

5.2.3 The SBS word begins at index count 80 and is between position identifiers P_8 and P_0 with a position identifier bit, P_9 between the 9^{th} and 10^{th} binary SBS coded bits. The SBS time code recycles each 24-hour period.

5.2.4 The eighteen control bits occur between position identifiers P_6 and P_8 with a position identifier occurring every 10 bits.

5.2.5 The frame rate or repetition rate is 0.1 seconds with resolutions of 1 ms (dc level shift) and 0.1 ms (modulated 10 kHz carrier).

5.3 Time Code Format B

5.3.1 The 74-bit time code contains 30 bits of BCD time-of-year information in days, hours, minutes and seconds, 17 bits of SB seconds-of-day, 9 bits for year information and 18 bits for control functions.

5.3.2 The BCD code (seconds sub-word) begins at index count 1 (LSB first) with binary coded bits occurring between position identifier bits P_0 and P_6: 7 for seconds, 7 for minutes, 6 for hours, 10 for days and 9 for year information between position identifiers P_5 and P_6 to complete the BCD word. An index marker occurs between the decimal digits in each sub-word to provide separation for visual resolution.

5.3.3 The SBS word begins at index count 80 and is between position identifiers P_8 and P_0 with a position identifier bit, P_9 between the 9th and 10th SBS coded bits. The SBS time code recycles each 24-hour period.

5.3.4 The eighteen control bits occur between position identifiers P_6 and P_8 with a position identifier every 10 bits.

5.3.5 The frame rate is 1.0 seconds with resolutions of 10 ms (dc level shift) and 1 ms (modulated 1 kHz carrier).

5.4 Time Code Format D

5.4.1 The 25-bit time code contains 16 bits of BCD Time-of-year information in days, hours, minutes and 9 bits for control functions.

5.4.2 The BCD code (hours sub-word) begins at index count 20 (LSB first) with binary coded bits occurring between position identifier bits P_2 and P_5: 6 for hours and 10 for days to complete the BCD word. An index marker occurs between the decimal digits in each sub-word for visual resolution. The BCD time-of-year code recycles yearly.

5.4.3 The nine control bits occur between position identifiers P_5 and P_0.

5.4.4 The frame rate is one hour with resolutions of 1 minute (dc level shift), 10 ms (modulated 100 Hz carrier) and 1 ms (modulated 1 kHz carrier).

5.5 Time Code Format E

5.5.1 The 71-bit time code contains 26 bits of BCD time-of-year information in days, hours, minutes, and seconds, 9 bits for year information, and 36 bits for control functions between position identifiers P_6 and P_0.

5.5.2 The BCD code (seconds sub-word) begins at index count 6 (LSB first). Binary coded Bits occur between position identifiers P_0 and P_5: 3 bits for tens of seconds, 7 for minutes, 6 for hours, 10 for days and 9 bits for year information between position identifiers P_5 and P_6 to complete the BCD word. An index marker occurs between the decimal digits in each sub-word to provide visual resolution. The BCD time-of-year code recycles yearly.

5.5.3 The eighteen control bits occur between position identifiers P_6 and P_0.

5.5.4 The frame rate is 10 seconds with resolutions of 0.1 seconds (dc level shift), 10 ms (modulated 100 Hz carrier), and 1 ms (modulated 1 kHz carrier).

5.6 Time Code Format G

5.6.1 The 74-bit time code contains 38 bits of BCD time-of-year information in days, hours, minutes, seconds, and fraction of seconds, 9 bits of year information, and 27 bits for control functions.

5.6.2 The BCD code (seconds sub-word) begins at index count 1 (LSB first). Binary coded bits occur between position identifiers P_0 and P_6: 7 bits for seconds, 7 for minutes, 6 for hours, 10 for days, 4 for tenths of seconds, 4 for hundredths of seconds and 9 for year information between position identifiers P_6 and P_7 to complete the BCD word. An index marker occurs between the decimal digits in each sub-word (except fractional seconds) to provide for visual resolution. The BCD time-of-year code recycles yearly.

5.6.3 The twenty-seven control bits occur between position identifiers P_7 and P_0.

5.6.4 The frame rate is 10 ms with resolutions of 0.1 ms (dc level shift) and 10s (100 kHz carrier).

5.7 Time Code Format H

5.7.1 The 32-bit time code word contains 23 bits of BCD time-of-year information in days, hours, and minutes and 9 bits for control functions.

5.7.2 The BCD code (minutes sub-word) begins at index count 10 (LSB first) with binary coded bits occurring between position identifier bits P_1 and P_5: 7 bits for minutes, 6 for hours, and 10 for days to complete the BCD word. An index marker occurs between decimal digits in each sub-word to provide separation for visual resolution. The time code recycles yearly.

5.7.3 The nine control bits occur between position identifiers P_5 and P_0.

5.7.4 The frame rate is 1 minute with resolutions of 1 second (dc level shift), 10 ms (modulated 100 Hz carrier) and 1 ms (modulated 1 kHz carrier).

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CHAPTER 6

DETAILED DESCRIPTION OF TIME CODES

6.1 Introduction

Detailed descriptions of individual time code formats are shown in the following paragraphs.

6.2 Format A

6.2.1 The beginning of each 0.1 second time frame is identified by two consecutive 0.8 ms bits, P_0 and P_r. The leading edge of P_r is the on-time reference point for the succeeding time code words. Position identifiers, P_0 and P_1 through P_9, (0.8 ms duration) occur every 10th bit and 1 ms before the leading edge of each succeeding 100 pps on-time bit (see Figure 6-1).

6.2.2 The three time code words and the control functions presented during the time frame are pulse width coded. The binary zero and index markers have duration of 0.2 ms, and the binary one has duration of 0.5 ms. The 1 k pps leading edge is the on-time reference point for all bits.

6.2.3 The binary coded decimal (BCD) time-of-year coded word consists of 34 bits beginning at index count one. The time-of-year sub-word bits occur between position identifiers P_0 and P_5: 7 bits for seconds, 7 for minutes, 6 for hours, 10 for days, 4 for tenths of seconds. Nine bits for year information occur between position identifiers P_5 and P_6 to complete the BCD time code word. An index marker occurs between the decimal digits in each sub-word, except tenths of seconds, to provide separation for visual resolution. The LSB occurs first except for the fractional seconds sub-word that follows the day-of-year sub-word. The BCD time-of-year code recycles yearly.

6.2.4 Eighteen control bits occur between position identifiers P_6 and P_8. Any control function bit or combination of bits can be programmed to read a binary one or a binary zero during any specified number of frames. Each control bit position is identified in Table 6-1.

6.2.5 The straight binary (SB) seconds-of-day code word occurs at index count 80 between position identifiers P_8 and P_0. Seventeen bits give time-of-day in seconds with the LSB occurring first. A position identifier occurs between the 9^{th} and 10^{th} binary seconds. The code recycles each 24-hour period.

6.2.6 Control bit assignments, functions, and parameters for time code Format A are shown on the following pages as:

Table 6-2: Identifies the control bit assignments for year information.
Table 6-3: Identifies the control functions (for 27 bits).
Table 6-4: Identifies the parameters that characterize the time code for Format A.

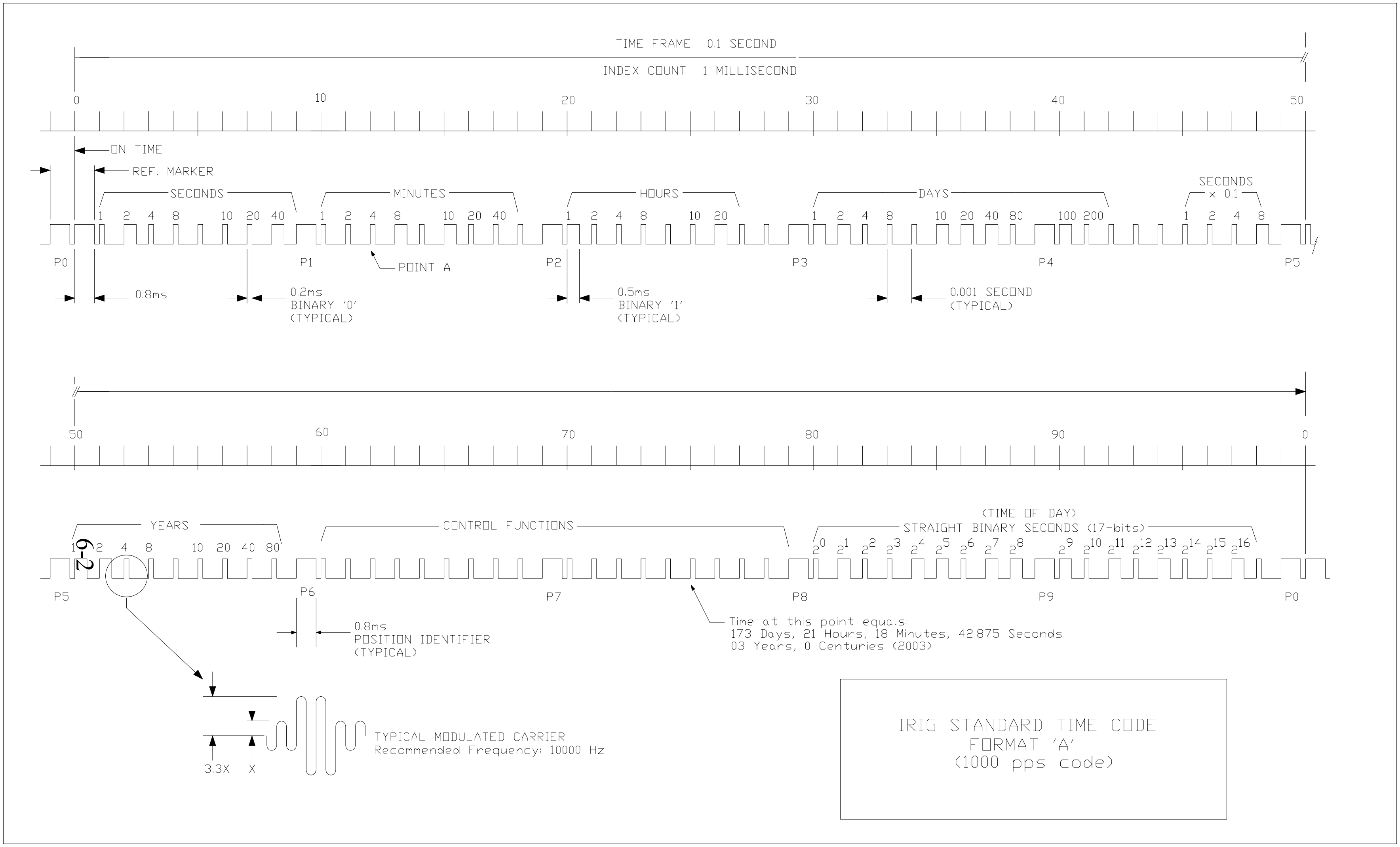

Figure 6-1. Format A: BCD time-of-year in days, hours, minutes, seconds, fractions of seconds and year, and straight binary seconds-of-day and control bits.

TABLE 6-1. FORMAT A, SIGNAL A000

BCD TIME-OF-YEAR CODE (34 DIGITS)

SECONDS SUBWORD			MINUTES SUBWORD			HOURS SUBWORD			DAYS AND FRACTIONAL SECOND SUBWORDS					
BCD Code Digit No.	**Subword Digit Wt SECONDS**	**BIT Time (Note 1)**	**BCD Code Digit No.**	**Subword Digit Wt MINUTES**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt HOURS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**
Reference BIT		P_r	8	1	P_r + 10 ms	15	1	P_r + 20 ms	21	1	P_r + 30 ms	29	100	P_r + 40 ms
1	1	P_r + 1 ms	9	2	P_r + 11 ms	16	2	P_r + 21 ms	22	2	P_r + 31 ms	30	200	P_r + 41 ms
2	2	P_r + 2 ms	10	4	P_r + 12 ms	17	4	P_r + 22 ms	23	4	P_r + 32 ms	Index BIT		P_r + 42 ms
3	4	P_r + 3 ms	11	8	P_r + 13 ms	18	8	P_r + 23 ms	24	8	P_r + 33 ms	Index BIT		P_r + 43 ms
4	8	P_r + 4 ms	Index BIT		P_r + 14 ms	Index BIT		P_r + 24 ms	Index BIT		P_r + 34 ms	Index BIT		P_r + 44 ms
Index BIT		P_r + 5 ms	12	10	P_r + 15 ms	19	10	P_r + 25 ms	25	10	P_r + 35 ms	31	0.1	P_r + 45 ms
5	10	P_r + 6 ms	13	20	P_r + 16 ms	20	20	P_r + 26 ms	26	20	P_r + 36 ms	32	0.2	P_r + 46 ms
6	20	P_r + 7 ms	14	40	P_r + 17 ms	Index BIT		P_r + 27 ms	27	40	P_r + 37 ms	33	0.4	P_r + 47 ms
7	40	P_r + 8 ms	Index BIT		P_r + 18 ms	Index BIT		P_r + 28 ms	28	80	P_r + 38 ms	34	0.8	P_r + 48 ms
Position Ident. (P_1)		P_r + 9 ms	Position Ident. (P_2)		P_r + 19 ms	Position Ident. (P_3)		P_r + 29 ms	Position Ident. (P_4)		P_r + 39 ms	Position Ident. (P_5)		P_r + 49 ms

YEAR AND CONTROL FUNCTIONS (27 BITS)

Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	P_r + 50 ms Units of Year 01	10	P_r + 60 ms	19	P_r + 70 ms
2	Units of Year 02	11	P_r + 61 ms	20	P_r + 71 ms
3	Units of Year 04	12	P_r + 62 ms	21	P_r + 72 ms
4	Units of Year 08	13	P_r + 63 ms	22	P_r + 73 ms
5	P_r + 54 ms	14	P_r + 64 ms	23	P_r + 74 ms
6	Tens of Year 10	15	P_r + 65 ms	24	P_r + 75 ms
7	Tens of Year 20	16	P_r + 66 ms	25	P_r + 76 ms
8	Tens of Year 40	17	P_r + 67 ms	26	P_r + 77 ms
9	Tens of Year 80	18	P_r + 68 ms	27	P_r + 78 ms
Position Ident. (P_6)	P_r + 59 ms	Position Ident. (P_7)	P_r + 69 ms	Position Ident. (P_8)	P_r + 79 ms

STRAIGHT BINARY SECONDS TIME-OF-DAY CODE (17 DIGITS)

SB Code BIT	**Subword Digit Weight**	**BIT Time**	**SB Code BIT**	**Subword Digit Weight**	**BIT Time**
1	2^0 = (1)	P_r + 80 ms	10	2^9 = (512)	P_r + 90 ms
2	2^1 = (2)	P_r + 81 ms	11	2^{10} = (1024)	P_r + 91 ms
3	2^2 = (4)	P_r + 82 ms	12	2^{11} = (2048)	P_r + 92 ms
4	2^3 = (8)	P_r + 83 ms	13	2^{12} = (4096)	P_r + 93 ms
5	2^4 = (16)	P_r + 84 ms	14	2^{13} = (8192)	P_r + 94 ms
6	2^5 = (32)	P_r + 85 ms	15	2^{14}=(16384)	P_r + 95 ms
7	2^6 = (64)	P_r + 86 ms	16	2^{15}=(32768)	P_r + 96 ms
8	2^7 = (128)	P_r + 87 ms	17	2^{16}=(65536)	P_r + 97 ms
9	2^8 = (256)	P_r + 88 ms	Index BIT		P_r + 98 ms
Position Ident. (P_9)		P_r + 89 ms	Position Ident. (P_0)		P_r + 99 ms

Note 1. The BIT Time is the time of the BIT leading edge and refers to the leading edge of Pr.

TABLE 6-2. IRIG-A CONTROL BIT ASSIGNMENT FOR YEAR INFORMATION			
POS. ID	**CTRL BIT NO**	**DESIGNATION**	**EXPLANATION**
P0 to P5 is BCD Time-of-year in seconds, minutes, hours, days, and fractional seconds.			
P49	--	P5	Position Identifier # 5
P50	1	Year, BCD 1	Last 2 digits of year in BCD
P51	2	Year, BCD 2	IBID
P52	3	Year, BCD 4	IBID
P53	4	Year, BCD 8	IBID
P54	5	Not Used	Unassigned
P55	6	Year, BCD 10	Last 2 digits of year in BCD
P56	7	Year, BCD 20	IBID
P57	8	Year, BCD 40	IBID
P58	9	Year, BCD 80	IBID
P59	--	P6	Position Identifier # 6
P60	10	Not Used	Unassigned
P61	11	IBID	IBID
P62	12	IBID	IBID
P63	13	IBID	IBID
P64	14	IBID	IBID
P65	15	IBID	IBID
P66	16	IBID	IBID
P67	17	IBID	IBID
P68	18	IBID	IBID
P69	--	P7	Position Identifier # 7
P70	19	Not Used	Unassigned
P71	20	IBID	IBID
P72	21	IBID	IBID
P73	22	IBID	IBID
P74	23	IBID	IBID
P75	24	IBID	IBID
P76	25	IBID	IBID
P77	26	IBID	IBID
P78	27	IBID	IBID
P79	--	P8	Position Identifier # 8
P6 to P8 are control functions			
P8 to P0 is Time-of-Day in Straight Binary Seconds.			

TABLE 6-3. FORMAT A CONTROL FUNCTIONS (27 BITS)					
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	Units of Year 01 P_r + 50 ms	10	P_r + 60 ms	19	P_r + 70 ms
2	Units of Year 02	11	P_r + 61 ms	20	P_r + 71 ms
3	Units of Year 04	12	P_r + 62 ms	21	P_r + 72 ms
4	Units of Year 08	13	P_r + 63 ms	22	P_r + 73 ms
5	P_r + 54 ms	14	P_r + 64 ms	23	P_r + 74 ms
6	Tens of Year 10	15	P_r + 65 ms	24	P_r + 75 ms
7	Tens of Year 20	16	P_r + 66 ms	25	P_r + 76 ms
8	Tens of Year 40	17	P_r + 67 ms	26	P_r + 77 ms
9	Tens of Year 80	18	P_r + 68 ms	27	P_r + 78 ms
Position Ident. (P_6)	P_r + 59 ms	Position Ident. (P_7)	P_r + 69 ms	Position Ident (P_8)	P_r + 79 ms
Note: The BIT Time is the time of the BIT leading edge and refers to the leading edge of P_r.					

TABLE 6-4. PARAMETERS FOR FORMAT A	
Pulse Rates	**Pulse Duration**
Bit rate: 1 k pps Position identifier rate: 100 pps Reference marker: 10 pps	Index marker: 0.2 ms Binary zero or unencoded bit: 0.2 ms Binary one or coded bit: 0.5 ms Position identifiers: 0.8 ms Reference bit: 0.8 ms
Resolution	**Mark-To-Space Ratio**
1 ms dc level 0.1 ms modulated 10 kHz carrier	Nominal value of 10:3 Range of 3:1 to 6:1

6.3 Format B

6.3.1 The beginning of each 1.0 second time frame is identified by two consecutive 8.0 ms bits, P_0 and P_r. The leading edge of P_r is the on-time reference point for the succeeding time code words. Position identifiers, P_0 and P_1 through P_9, (8 ms duration) occur every 10th bit and 10 ms before the leading edge of each succeeding 10 pps "on-time" bits (see Figure 6-2).

6.3.2 The three time code words and the control functions presented during the time frame are pulse width coded. The binary zero and the index markers have duration of 2.0 ms, and a binary one has duration of 5.0 ms. The 100 pps leading edge is the on-time reference point for all bits.

6.3.3 The BCD time-of-year code word consists of 30 bits beginning at index count one. The sub-word bits occur between position identifiers P_0 and $P_{5;}$ there are 7 bits for seconds, 7 for minutes, 6 for hours, and 10 for days. Nine bits for year information occur between position identifiers P_5 and P_6 to complete the BCD time code word. An index marker occurs between the decimal digits in each sub-word to provide separation for visual resolution. The LSB occurs first. The BCD time-of-year code recycles yearly. Each bit position is identified in Table 6-5.

6.3.4 Eighteen control functions occur between position identifiers P_6 and P_8. Any control function bit or combination of bits can be programmed to read a binary one or zero during any specified number of time frames.

6.3.5 The SB seconds-of-day word occurs between position identifier P_8 and P_0. A position identifier occurs between the 9^{th} and 10^{th} binary coded bit. The code recycles each 24-hour period.

6.3.6 Control bit assignments, functions, and parameters for time code format B are shown on the following pages as:

Table 6-6: Identifies the control bit assignments for year information.
Table 6-7: Identifies the control functions (for 27 bits).
Table 6-8: Identifies the parameters that characterize the time code for Format A.

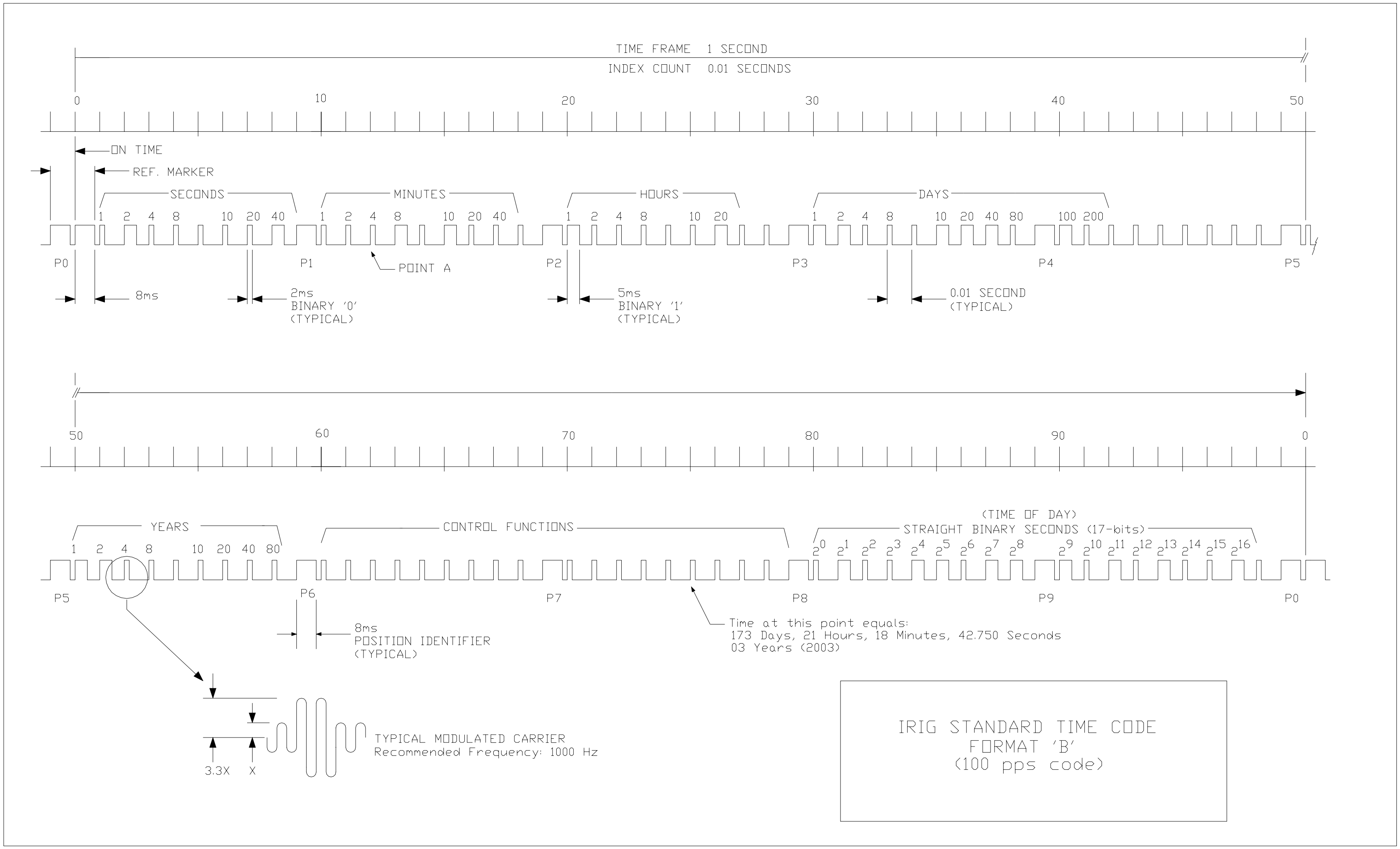

Figure 6-2. Format B: BCD time-of-year in days, hours, minutes, seconds and year and straight binary seconds-of-day and control bits.

TABLE 6-5. FORMAT B, SIGNAL B000

BCD TIME-OF-YEAR CODE (30 DIGITS)

SECONDS SUBWORD			MINUTES SUBWORD			HOURS SUBWORD			DAYS SUBWORD					
BCD Code Digit No.	**Subword Digit Wt SECONDS**	**BIT Time (Note 1)**	**BCD Code Digit No.**	**Subword Digit Wt MINUTES**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt HOURS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**
Reference BIT		P_r	8	1	P_r + 100 ms	15	1	P_r + 200 ms	21	1	P_r + 300 ms	29	100	P_r + 400 ms
1	1	P_r + 10 ms	9	2	P_r + 110 ms	16	2	P_r + 210 ms	22	2	P_r + 310 ms	30	200	P_r + 410 ms
2	2	P_r + 20 ms	10	4	P_r + 120 ms	17	4	P_r + 220 ms	23	4	P_r + 320 ms	Index BIT		P_r + 420 ms
3	4	P_r + 30 ms	11	8	P_r + 130 ms	18	8	P_r + 230 ms	24	8	P_r + 330 ms	Index BIT		P_r + 430 ms
4	8	P_r + 40 ms	Index BIT		P_r + 140 ms	Index BIT		P_r + 240 ms	Index BIT		P_r + 340 ms	Index BIT		P_r + 440 ms
Index BIT		P_r + 50 ms	12	10	P_r + 150 ms	19	10	P_r + 250 ms	25	10	P_r + 350 ms	Index BIT		P_r + 450 ms
5	10	P_r + 60 ms	13	20	P_r + 160 ms	20	20	P_r + 260 ms	26	20	P_r + 360 ms	Index BIT		P_r + 460 ms
6	20	P_r + 70 ms	14	40	P_r + 170 ms	Index BIT		P_r + 270 ms	27	40	P_r + 370 ms	Index BIT		P_r + 470 ms
7	40	P_r + 80 ms	Index BIT		P_r + 180 ms	Index BIT		P_r + 280 ms	28	80	P_r + 380 ms	Index BIT		P_r + 480 ms
Position Ident. (P_1)		P_r + 90 ms	Position Ident. (P_2)		P_r + 190 ms	Position Ident. (P_3)		P_r + 290 ms	Position Ident. (P_4)		P_r + 390 ms	Position Ident. (P_5)		P_r + 490 ms

YEAR AND CONTROL FUNCTIONS (27 BITS)

Control Function BIT	BIT Time	Control Function BIT	BIT Time	Control Function BIT	BIT Time
1	P_r + 500 ms Units of Year 01	10	P_r + 600 ms	19	P_r + 700 ms
2	Units of Year 02	11	P_r + 610 ms	20	P_r + 710 ms
3	Units of Year 04	12	P_r + 620 ms	21	P_r + 720 ms
4	Units of Year 08	13	P_r + 630 ms	22	P_r + 730 ms
5	P_r + 540 ms	14	P_r + 640 ms	23	P_r + 740 ms
6	Tens of Year 10	15	P_r + 650 ms	24	P_r + 750 ms
7	Tens of Year 20	16	P_r + 660 ms	25	P_r + 760 ms
8	Tens of Year 40	17	P_r + 670 ms	26	P_r + 770 ms
9	Tens of Year 80	18	P_r + 680 ms	27	P_r + 780 ms
Position Ident. (P_6)	P_r + 590 ms	Position Ident. (P_7)	P_r + 690 ms	Position Ident. (P_8)	P_r + 790 ms

STRAIGHT BINARY SECONDS TIME-OF-DAY CODE (17 DIGITS)

SB Code BIT	Sub-word Digit Weight	BIT Time	SB Code BIT	Subword Digit Weight	BIT Time
1	2^0 = (1)	P_r + 800 ms	10	2^9 = (512)	P_r + 900 ms
2	2^1 = (2)	P_r + 810 ms	11	2^{10} = (1024)	P_r + 910 ms
3	2^2 = (4)	P_r + 820 ms	12	2^{11} = (2048)	P_r + 920 ms
4	2^3 = (8)	P_r + 830 ms	13	2^{12} = (4096)	P_r + 930 ms
5	2^4 = (16)	P_r + 840 ms	14	2^{13} = (8192)	P_r + 940 ms
6	2^5 = (32)	P_r + 850 ms	15	2^{14}=(16384)	P_r + 950 ms
7	2^6 = (64)	P_r + 860 ms	16	2^{15}=(32768)	P_r + 960 ms
8	2^7 = (128)	P_r + 870 ms	17	2^{16}=(65536)	P_r + 970 ms
9	2^8 = (256)	P_r + 880 ms	Index BIT		P_r + 980 ms
Position Ident. (P_9)		P_r + 890 ms	Position Ident. (P_0)		P_r + 990 ms

Note 1: The BIT Time is the time of the BIT leading edge and refers to the leading edge of Pr

TABLE 6-6. IRIG-B CONTROL BIT ASSIGNMENT FOR YEAR INFORMATION			
POS. ID	**CTRL BIT NO**	**DESIGNATION**	**EXPLANATION**
P0 to P5 is BCD Time-of-Year in Seconds, Minutes, Hours and Days.			
P49	--	P5	Position Identifier # 5
P50	1	Year, BCD 1	Last 2 digits of year in BCD
P51	2	Year, BCD 2	IBID
P52	3	Year, BCD 4	IBID
P53	4	Year, BCD 8	IBID
P54	5	Not Used	Unassigned
P55	6	Year, BCD 10	Last 2 digits of year in BCD
P56	7	Year, BCD 20	IBID
P57	8	Year, BCD 20	IBID
P58	9	Year, BCD 20	IBID
P59	--	P6	Position Identifier # 6
P60	10	Not Used	Unassigned
P61	11	IBID	IBID
P62	12	IBID	IBID
P63	13	IBID	IBID
P64	14	IBID	IBID
P65	15	IBID	IBID
P66	16	IBID	IBID
P67	17	IBID	IBID
P68	18	IBID	IBID
P69	--	P7	Position Identifier # 7
P70	19	Not Used	Unassigned
P71	20	IBID	IBID
P72	21	IBID	IBID
P73	22	IBID	IBID
P74	23	IBID	IBID
P75	24	IBID	IBID
P76	25	IBID	IBID
P77	26	IBID	IBID
P78	27	IBID	IBID
P79	--	P8	Position Identifier # 8
P6 to P8 are control functions			
P8 to P0 is Time-of-Day in Straight Binary Seconds.			

TABLE 6-7. FORMAT B CONTROL FUNCTIONS (45 BITS)					
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	Units of Year 01 P_r + 5.0 sec	10	P_r + 6.0 sec	19	P_r + 7.0 sec
2	Units of Year 02	11	P_r + 6.1 sec	20	P_r + 7.1 sec
3	Units of Year 03	12	P_r + 6.2 sec	21	P_r + 7.2 sec
4	Units of Year 04	13	P_r + 6.3 sec	22	P_r + 7.3 sec
5	P_r + 5.4 sec	14	P_r + 6.4 sec	23	P_r + 7.4 sec
6	Tens of Year 10	15	P_r + 6.5 sec	24	P_r + 7.5 sec
7	Tens of Year 20	16	P_r + 6.6.sec	25	P_r + 7.6 sec
8	Tens of Year 40	17	P_r + 6.7 sec	26	P_r + 7.7 sec
9	Tens of Year 80	18	P_r + 6.8 sec	27	P_r + 7.8 sec
Position Ident. (P_6)	P_r + 5.9 sec	Position Ident. (P_7)	P_r + 6.9 sec	Position Ident. (P_8)	P_r + 7.9 sec
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
28	P_r + 8.0 sec	37	P_r + 9.0 sec	BLANK	BLANK
29	P_r + 8.1 sec	38	P_r + 9.1 sec		
30	P_r + 8.2 sec	39	P_r + 9.2 sec		
31	P_r + 8.3 sec	40	P_r + 9.3 sec		
32	P_r + 8.4 sec	42	P_r + 9.4 sec		
33	P_r + 8.5 sec	42	P_r + 9.5 sec		
34	P_r + 8.6 sec	43	P_r + 9.6 sec		
35	P_r + 8.7 sec	44	P_r + 9.7 sec		
35	P_r + 8.8 sec	45	P_r + 9.8 sec		
Position Ident. (P9)	P_r + 8.9 sec	Position Ident. (P0)	P_r + 9.9 sec		

TABLE 6-8. PARAMETERS FOR FORMAT B	
Pulse Rates	**Pulse Duration**
Bit rate: 100 pps Position identifier: 10 pps Reference mark: 1 pps	Index marker: 2 ms Binary zero or unencoded bit: 2 ms Binary one or coded bit: 5 ms Position identifiers: 8 ms Reference bit: 8 ms
Resolution	**Mark-To-Space Ratio**
10 ms dc level 1 ms modulated 1 kHz carrier	Nominal value of 10:3 Range of 3:1 to 6:1

6.4 Format D

6.4.1 The beginning of each 2-hour time frame is identified by two consecutive 48-second bits, P_0 and P_r. The leading edge of P_r is the on-time point for the succeeding time code word. Position identifiers, P_0 and P_1 through P_5, occur every 10th bit and one minute before the leading edge of each succeeding 6 pulses per hour (pph) on-time bit (see Figure 6-3).

6.4.2 The time code word and the control bits presented during the time frame are pulse width coded. The binary zero and the index markers each have duration of 12 seconds and the binary one has duration of 30 seconds. The 1-ppm leading edge is the on-time reference point for all bits.

6.4.3 The BCD time-of-year code consists of 16 bits beginning at index count 20. The sub-word bits occur between position identifiers P_2 and P_5: 6 for hours and 10 for days to complete the time code word. An index marker occurs between the decimal digits in each sub-word to provide separation for visual resolution. The LSB occurs first. The code recycles yearly. Each bit position is identified in Table 6-9.

6.4.4 Nine control bits occur between position identifiers P_5 and P_0. Any control function bit or combination of bits can be programmed to read a binary one or zero during any specified number of time frames.

6.4.5 Details of the IRIG Format D parameters that characterize the time code for Format D are shown in Table 6-10.

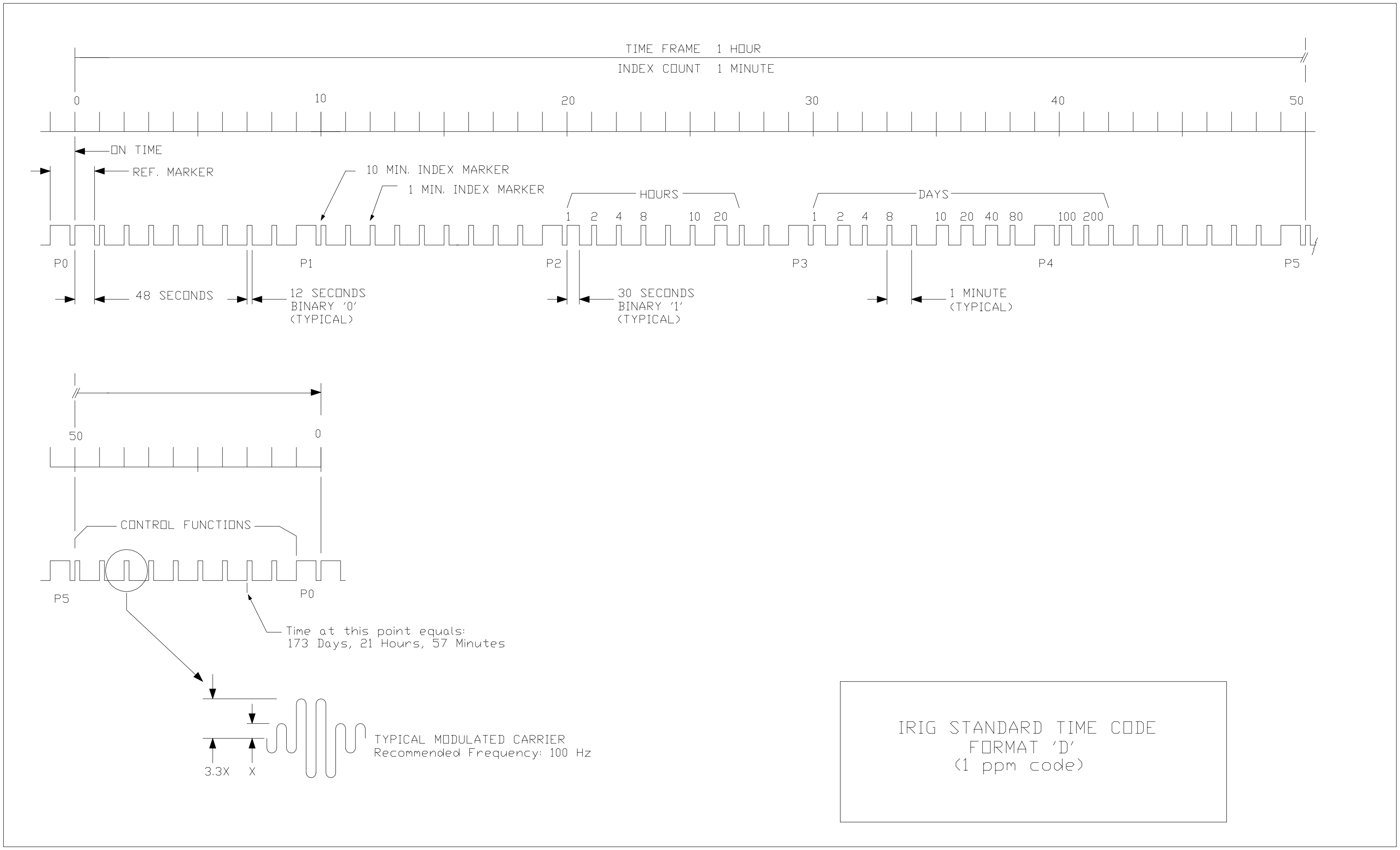

Figure 6-3. Format D: BCD time-of-year in days and hours and control bits.

TABLE 6-9. FORMAT D, SIGNAL D001

BCD TIME-OF-YEAR CODE (16 DIGITS)														
MINUTES SUBWORD						HOURS SUBWORD			DAYS SUBWORD					
BCD Code Digit No.	Subword Digit Wt MINUTES	BIT Time (Note 1)	BCD Code Digit No.	Subword Digit Wt MINUTES	BIT Time	BCD Code Digit No.	Subword Digit Wt HOURS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time
Reference BIT		P_r	Index Marker		$P_r + 10$ min	1	1	$P_r + 20$ min	7	1	$P_r + 30$ min	15	100	$P_r + 40$ min
Index Marker		$P_r + 1$ min	Index Marker		$P_r + 11$ min	2	2	$P_r + 21$ min	8	2	$P_r + 31$ min	16	200	$P_r + 41$ min
Index Marker		$P_r + 2$ min	Index Marker		$P_r + 12$ min	3	4	$P_r + 22$ min	9	4	$P_r + 32$ min	Index Marker		$P_r + 42$ min
Index Marker		$P_r + 3$ min	Index Marker		$P_r + 13$ min	4	8	$P_r + 23$ min	10	8	$P_r + 33$ min	Index Marker		$P_r + 43$ min
Index Marker		$P_r + 4$ min	Index Marker		$P_r + 14$ min	Index Marker		$P_r + 24$ min	Index BIT		$P_r + 34$ min	Index Marker		$P_r + 44$ min
Index Marker		$P_r + 5$ min	Index Marker		$P_r + 15$ min	5	10	$P_r + 25$ min	11	10	$P_r + 35$ min	Index Marker		$P_r + 45$ min
Index Marker		$P_r + 6$ min	Index Marker		$P_r + 16$ min	6	20	$P_r + 26$ min	12	20	$P_r + 36$ min	Index Marker		$P_r + 46$ min
Index Marker		$P_r + 7$ min	Index Marker		$P_r + 17$ min	Index Marker		$P_r + 27$ min	13	40	$P_r + 37$ min	Index Marker		$P_r + 47$ min
Index Marker		$P_r + 8$ min	Index Marker		$P_r + 18$ min	Index Marker		$P_r + 28$ min	14	80	$P_r + 38$ min	Index Marker		$P_r + 48$ min
Position Ident. (P_1)		$P_r + 9$ min	Position Ident. (P_2)		$P_r + 19$ min	Position Ident. (P_3)		$P_r + 29$ min	Position Ident. (P_4)		$P_r + 39$ min	Position Ident. (P_5)		$P_r + 49$ min

CONTROL FUNCTIONS (9 BITS)	
Control Function BIT	BIT Time
1	$P_r + 50$ min
2	$P_r + 51$ min
3	$P_r + 52$ min
4	$P_r + 53$ min
5	$P_r + 54$ min
6	$P_r + 55$ min
7	$P_r + 56$ min
8	$P_r + 57$ min
9	$P_r + 58$ min
Position Ident. (P_0)	$P_r + 59$ min

Note: The BIT Time is the time of the BIT leading edge and refers to the leading edge of Pr.

TABLE 6-10. PARAMETERS FOR FORMAT D	
Pulse Rates	**Pulse Duration**
Bit rate: 1 ppm Position identifiers: 6 pph Reference mark: 1 pph	Index marker: 12 s Binary zero or unencoded bit: 12 s Binary one or coded bit: 30 s Position identifiers: 48 s Reference bit: 48 s
Resolution	**Mark-To-Space Ratio**
1 m dc level 10 ms modulated 100 Hz carrier 1 ms modulated 1 kHz carrier	Nominal value of 10:1 Range of 3:1 to 6:1

6.5 Format E

6.5.1 The beginning of each 10 second time frame is identified by two consecutive 80 ms bits, P_0 and P_r. The leading edge of P_r is the on-time reference point for the succeeding time code. Position identifiers, P_0 and P_1 through P_9, occur every 10th bit and 0.1 seconds before the leading edge of each succeeding 1 pps on-time bit (see Figure 6-4).

6.5.2 The time code word and control functions presented during the time frame are pulse width coded. The binary zero and index markers have duration of 20 ms, and the binary one has duration of 50 ms. The 10 pps leading edge is the on-time reference point for all bits.

6.5.3 The BCD time-of year code word consists of 26 bits beginning at index count 6. The coded sub-word bits occur between position identifiers P_0 and P_5: 3 for seconds, 7 for minutes, 6 for hours, and 10 for days. Nine bits for year information occur between position identifiers P_5 and P_6 to complete the BCD time code word. An index marker occurs between the decimal digits in each sub-word to provide separation for visual resolution. The LSB occurs first. The code recycles yearly. Each bit position is identified in Table 6-11.

6.5.4 Forty-five control functions occur between position identifiers P_6 and P_0. Any control function bit or combination of bits can be programmed to read a binary one or zero during any specified number of time frames.

6.5.5 Control bit assignments, functions, and parameters for time code format E are shown on the following pages as:

Table 6-12: IRIG-E control bit assignment for year information
Table 6-13: Format E control functions (45 bits)
Table 6-14: Parameters for format E

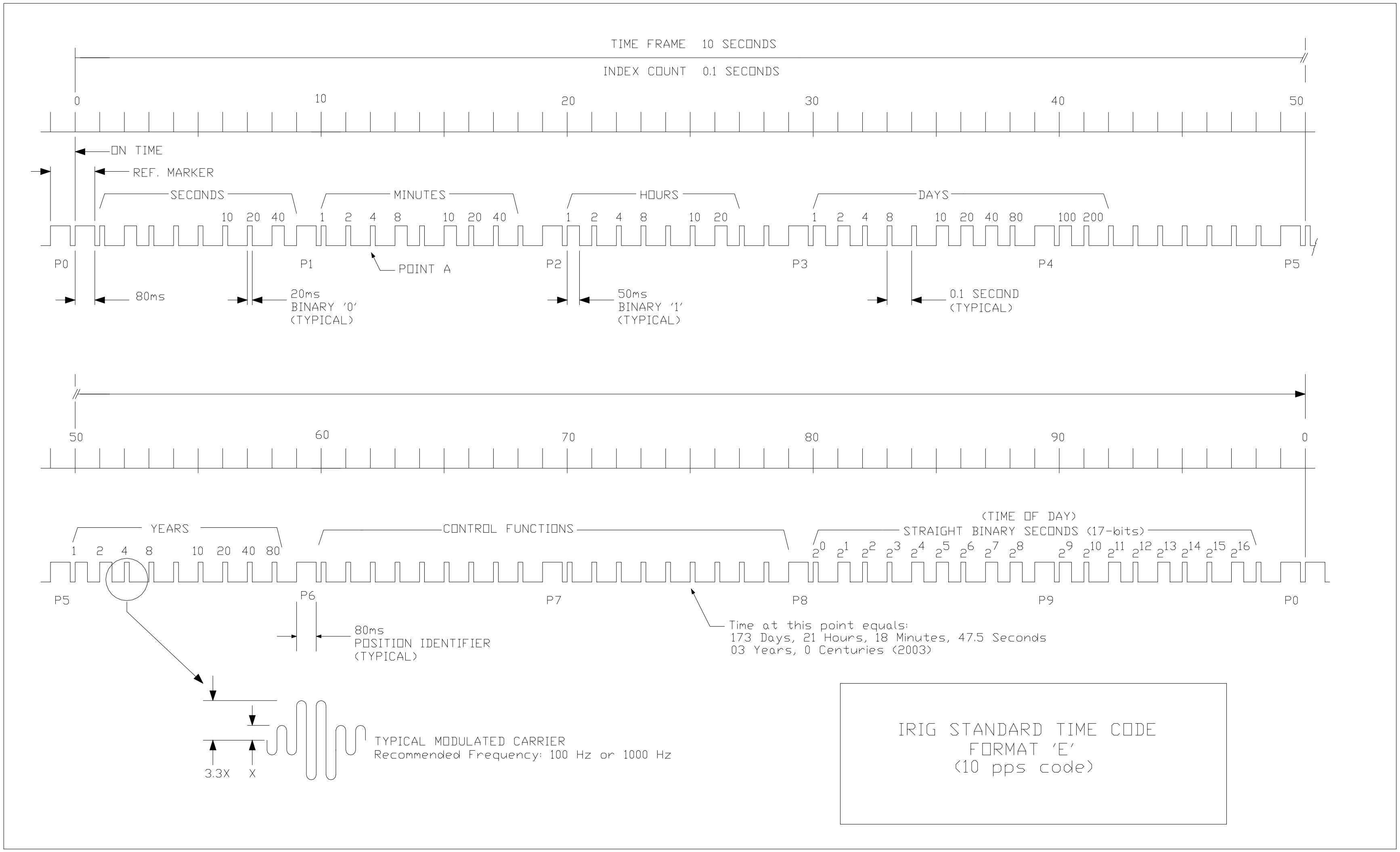

Figure 6-4. Format E: BCD time-of-year in days, hours, minutes, seconds, and year and control bits.

TABLE 6-11. FORMAT E, SIGNAL E001

BCD TIME-OF-YEAR CODE (26 DIGITS)

SECONDS SUBWORD			MINUTES SUBWORD			HOURS SUBWORD			DAYS SUBWORD					
BCD Code Digit No.	**Subword Digit Wt SECONDS**	**BIT Time (Note 1)**	**BCD Code Digit No.**	**Subword Digit Wt MINUTES**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt HOURS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**	**BCD Code Digit No.**	**Subword Digit Wt DAYS**	**BIT Time**
Reference BIT		P_r	4	1	P_r + 1.0 sec	11	1	P_r + 2.0 sec	17	1	P_r + 3.0 sec	25	100	P_r + 4.0 sec
Index Marker		P_r + 0.1 sec	5	2	P_r + 1.1 sec	12	2	P_r + 2.1 sec	18	2	P_r + 3.1 sec	26	200	P_r + 4.1 sec
Index Marker		P_r + 0.2 sec	6	4	P_r + 1.2 sec	13	4	P_r + 2.2 sec	19	4	P_r + 3.2 sec	Index Marker		P_r + 4.2 sec
Index Marker		P_r + 0.3 sec	7	8	P_r + 1.3 sec	14	8	P_r + 2.3 sec	20	8	P_r + 3.3 sec	Index Marker		P_r + 4.3 sec
Index Marker		P_r + 0.4 sec	Index Marker		P_r + 1.4 sec	Index Marker		P_r + 2.4 sec	Index Marker		P_r + 3.4 sec	Index Marker		P_r + 4.4 sec
Index Marker		P_r + 0.5 sec	8	10	P_r + 1.5 sec	15	10	P_r + 2.5 sec	21	10	P_r + 3.5 sec	Index Marker		P_r + 4.5 sec
1	10	P_r + 0.6 sec	9	20	P_r + 1.6 sec	16	20	P_r + 2.6 sec	22	20	P_r + 3.6 sec	Index Marker		P_r + 4.6 sec
2	20	P_r + 0.7 sec	10	40	P_r + 1.7 sec	Index Marker		P_r + 2.7 sec	23	40	P_r + 3.7 sec	Index Marker		P_r + 4.7 sec
3	40	P_r + 0.8 sec	Index Marker		P_r + 1.8 sec	Index Marker		P_r + 2.8 sec	24	80	P_r + 3.8 sec	Index Marker		P_r + 4.8 sec
Position Ident. (P_1)		P_r + 0.9 sec	Position Ident. (P_2)		P_r + 1.9 sec	Position Ident. (P_3)		P_r + 2.9 sec	Position Ident. (P_4)		P_r + 3.9 sec	Position Ident. (P_5)		P_r + 4.9 sec

CONTROL FUNCTIONS (45 BITS)

Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	P_r + 5.0 sec	10	P_r + 6.0 sec	19	P_r + 7.0 sec	28	P_r + 8.0 sec	37	P_r + 9.0 sec
2	P_r + 5.1 sec	11	P_r + 6.1 sec	20	P_r + 7.1 sec	29	P_r + 8.1 sec	38	P_r + 9.1 sec
4	P_r + 5.2 sec	12	P_r + 6.2 sec	21	P_r + 7.2 sec	30	P_r + 8.2 sec	39	P_r + 9.2 sec
3	P_r + 5.3 sec	13	P_r + 6.3 sec	22	P_r + 7.3 sec	31	P_r + 8.3 sec	40	P_r + 9.3 sec
5	P_r + 5.4 sec	14	P_r + 6.4 sec	23	P_r + 7.4 sec	32	P_r + 8.4 sec	41	P_r + 9.4 sec
6	P_r + 5.5 sec	15	P_r + 6.5 sec	24	P_r + 7.5 sec	33	P_r + 8.5 sec	42	P_r + 9.5 sec
7	P_r + 5.6 sec	16	P_r + 6.6 sec	25	P_r + 7.6 sec	34	P_r + 8.6 sec	43	P_r + 9.6 sec
8	P_r + 5.7 sec	17	P_r + 6.7 sec	26	P_r + 7.7 sec	35	P_r + 8.7 sec	44	P_r + 9.7 sec
9	P_r + 5.8 sec	18	P_r + 6.8 sec	27	P_r + 7.8 sec	36	P_r + 8.8 sec	45	P_r + 9.8 sec
Position Ident. (P_6)	P_r + 5.9 sec	Position Ident. (P_7)	P_r + 6.9 sec	Position Ident. (P_8)	P_r + 7.9 sec	Position Ident. (P_9)	P_r + 8.9 sec	Position Ident (P_0)	P_r + 9.9 sec

Note 1: The BIT Time is the time of the BIT leading edge and refers to the leading edge of Pr.

TABLE 6-12. IRIG-E CONTROL BIT ASSIGNMENT FOR YEAR INFORMATION			
POS. ID	**CTRL BIT NO**	**DESIGNATION**	**EXPLANATION**
P0 to P5 is BCD Time-of-Year in Seconds, Minutes, Hours and Days.			
P49	--	P5	Position Identifier # 5
P50	1	Year, BCD 1	Last 2 digits of year in BCD
P51	2	Year, BCD 2	IBID
P52	3	Year, BCD 4	IBID
P53	4	Year, BCD 8	IBID
P54	5	Not Used	Unassigned
P55	6	Year, BCD 10	Last 2 digits of year in BCD
P56	7	Year, BCD 20	IBID
P57	8	Year, BCD 40	IBID
P58	9	Year, BCD 80	IBID
P59	--	P6	Position Identifier # 6
P60	10	Not Used	Unassigned
P61	11	IBID	IBID
P62	12	IBID	IBID
P63	13	IBID	IBID
P64	14	IBID	IBID
P65	15	IBID	IBID
P66	16	IBID	IBID
P67	17	IBID	IBID
P68	18	IBID	IBID
P69	--	P7	Position Identifier # 7
P6 to P0 are Control Functions			

TABLE 6-13. FORMAT E CONTROL FUNCTIONS (45 BITS)					
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	Units of Year 01 P_r + 5.0 sec	10	P_r + 6.0 sec	19	P_r + 7.0 sec
2	Units of Year 02	11	P_r + 6.1 sec	20	P_r + 7.1 sec
3	Units of Year 03	12	P_r + 6.2 sec	21	P_r + 7.2 sec
4	Units of Year 04	13	P_r + 6.3 sec	22	P_r + 7.3 sec
5	P_r + 5.4 sec	14	P_r + 6.4 sec	23	P_r + 7.4 sec
6	Tens of Year 10	15	P_r + 6.5 sec	24	P_r + 7.5 sec
7	Tens of Year 20	16	P_r + 6.6.sec	25	P_r + 7.6 sec
8	Tens of Year 40	17	P_r + 6.7 sec	26	P_r + 7.7 sec
9	Tens of Year 80	18	P_r + 6.8 sec	27	P_r + 7.8 sec
Position Ident. (P_6)	P_r + 5.9 sec	Position Ident. (P_7)	P_r + 6.9 sec	Position Ident. (P_8)	P_r + 7.9 sec
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
28	P_r + 8.0 sec	37	P_r + 9.0 sec	BLANK	BLANK
29	P_r + 8.1 sec	38	P_r + 9.1 sec		
30	P_r + 8.2 sec	39	P_r + 9.2 sec		
31	P_r + 8.3 sec	40	P_r + 9.3 sec		
32	P_r + 8.4 sec	42	P_r + 9.4 sec		
33	P_r + 8.5 sec	42	P_r + 9.5 sec		
34	P_r + 8.6 sec	43	P_r + 9.6 sec		
35	P_r + 8.7 sec	44	P_r + 9.7 sec		
35	P_r + 8.8 sec	45	P_r + 9.8 sec		
Position Ident. (P_9)	P_r + 8.9 sec	Position Ident. (P_0)	P_r + 9.9 sec		

TABLE 6-14. PARAMETERS FOR FORMAT E	
Pulse Rates	**Pulse Duration**
Bit rate: 10 pps Position identifier: 1 pps Reference mark: 6 ppm	Index marker: 20 ms Binary zero or unencoded bit: 20 ms Binary one or coded bit: 50 ms Position identifier: 80 ms Reference bit: 80 ms
Resolution	**Mark-To-Space Ratio**
0.1 s dc level 10 ms modulated 100 kHz carrier 1 ms modulated 1 kHz carrier	Nominal value of 10:3 Range of 3:1 to 6:1

6.6 Format G

6.6.1 The beginning of each 0.01-second time frame is identified by two consecutive 80 µs bits, P_0 and P_r. The leading edge of P_r is the on-time reference point for the succeeding time code. Position identifiers, P_0 and P_1 through P_9, occur every 10th bit, 0.1 ms before the leading edge of each succeeding 1 k pps on-time bit (see Figure 6-5).

6.6.2 The time code word and the control functions presented during the time frame are pulse width coded. The binary zero and index markers have durations of 20 µs, and the binary one has duration of 50 µs. The 10 k pps leading edge is the on-time reference point for all bits.

6.6.3 The BCD time-of-year code word consists of 38 bits beginning at index count one. The sub-word bits occur between position identifiers P_0 and P_6: 7 for seconds, 7 for minutes, 6 for hours, 10 for days, 4 for tenths of seconds, and 4 for hundredths of seconds. Nine bits for year information occur between position identifiers P_6 and P_7 to complete the BCD time code word. An index marker occurs between the decimal digits in each sub-word, except for fractional seconds, to provide visual separation. The LSB occurs first, except for the fractional second information that follows the day-of-year information. The code recycles yearly. Each bit position is identified in Table 6-15.

6.6.4 Twenty-seven control bits occur between position identifiers P_7 and P_0. Any control function bit or combination of bits can be programmed to read a binary one or zero during any specified number of time frames. Each control bit position is identified in table 6.

6.6.5 Control bit assignments, functions, and parameters for time code format G are shown on the following pages as:

Table 6-16: IRIG-G control bit assignment for year information
Table 6-17: Format G control functions (36 BITS)
Table 6-18: Parameters for format G

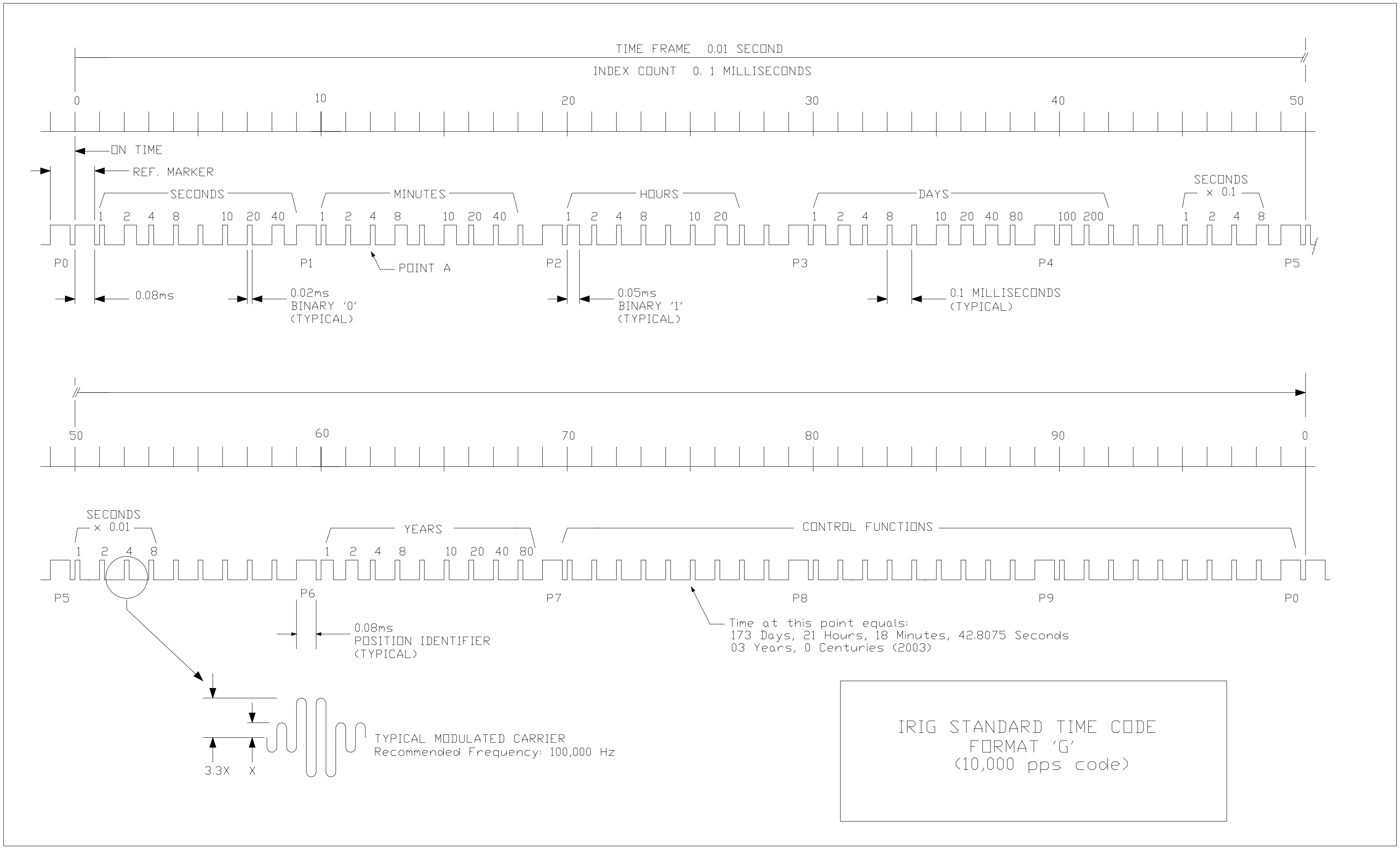

Figure 6-5. Format G: BCD Time-of-year in days, hours, minutes, seconds, and year and fractions-of-seconds, and control bits.

TABLE 6-15. FORMAT G, SIGNAL G001

BCD TIME-OF-YEAR CODE (38 DIGITS)														
SECONDS SUBWORD			MINUTES SUBWORD			HOURS SUBWORD			DAYS AND FRACTIONAL SECOND SUBWORD					
BCD Code Digit No.	Subword Digit Wt SECONDS	BIT Time (Note 1)	BCD Code Digit No.	Subword Digit Wt MINUTES	BIT Time	BCD Code Digit No.	Subword Digit Wt HOURS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time
Reference BIT		P_r	8	1	P_r + 1.0 ms	15	1	P_r + 2.0 ms	21	1	P_r + 3.0 ms	29	100	P_r + 4.0 ms
1	1	P_r + 0.1 ms	9	2	P_r + 1.1 ms	16	2	P_r + 2.1 ms	22	2	P_r + 3.1 ms	30	200	P_r + 4.1 ms
2	2	P_r + 0.2 ms	10	4	P_r + 1.2 ms	17	4	P_r + 2.2 ms	23	4	P_r + 3.2 ms	Index BIT		P_r + 4.2 ms
3	4	P_r + 0.3 ms	11	8	P_r + 1.3 ms	18	8	P_r + 2.3 ms	24	8	P_r + 3.3 ms	Index BIT		P_r + 4.3 ms
4	8	P_r + 0.4 ms	Index BIT		P_r + 1.4 ms	Index BIT		P_r + 2.4 ms	Index BIT		P_r + 3.4 ms	Index BIT		P_r + 4.4 ms
Index Bit		P_r + 0.5 ms	12	10	P_r + 1.5 ms	19	10	P_r + 2.5 ms	25	10	P_r + 3.5 ms	31	0.1	P_r + 4.5 ms
5	10	P_r + 0.6 ms	13	20	P_r + 1.6 ms	20	20	P_r + 2.6 ms	26	20	P_r + 3.6 ms	32	0.2	P_r + 4.6 ms
6	20	P_r + 0.7 ms	14	40	P_r + 1.7 ms	Index BIT		P_r + 2.7 ms	27	40	P_r + 3.7 ms	33	0.4	P_r + 4.7 ms
7	40	P_r + 0.8 ms	Index BIT		P_r + 1.8 ms	Index BIT		P_r + 2.8 ms	28	80	P_r + 3.8 ms	34	0.8	P_r + 4.8 ms
Position Ident. (P_1)		P_r + 0.9 ms	Position Ident. (P_2)		P_r + 1.9 ms	Position Ident. (P_3)		P_r + 2.9 ms	Position Ident. (P_4)		P_r + 3.9 ms	Position Ident. (P_5)		P_r + 4.9 ms

BCD TIME-OF-YEAR CODE (Cont'd)		
FRACTIONAL SECOND SUB-WORD		
BCD Code Digit No.	Subword Digit Wt SECONDS	BIT Time
35	0.01	P_r + 5.0 ms
36	0.02	P_r + 5.1 ms
37	0.04	P_r + 5.2 ms
38	0.08	P_r + 5.3 ms
Index BIT		P_r + 5.4 ms
Index BIT		P_r + 5.5 ms
Index BIT		P_r + 5.6 ms
Index BIT		P_r + 5.7 ms
Index BIT		P_r + 5.8 ms
Position Ident. (P_6)		P_r + 5.9 ms

YEAR AND CONTROL FUNCTIONS (36 BITS)							
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	P_r + 6.0 ms Units of Year 01	10	P_r + 7.0 ms	19	P_r + 8.0 ms	28	P_r + 9.0 ms
2	Units of Year 02	11	P_r + 7.1 ms	20	P_r + 8.1 ms	29	P_r + 9.1 ms
3	Units of Year 04	12	P_r + 7.2 ms	21	P_r + 8.2 ms	30	P_r + 9.2 ms
4	Units of Year 08	13	P_r + 7.3 ms	22	P_r + 8.3 ms	31	P_r + 9.3 ms
5	P_r + 6.4 ms	14	P_r + 7.4 ms	23	P_r + 8.4 ms	32	P_r + 9.4 ms
6	Tens of Year 10	15	P_r + 7.5 ms	24	P_r + 8.5 ms	33	P_r + 9.5 ms
7	Tens of Year 20	16	P_r + 7.6 ms	25	P_r + 8.6 ms	34	P_r + 9.6 ms
8	Tens of Year 40	17	P_r + 7.7 ms	26	P_r + 8.7 ms	35	P_r + 9.7 ms
9	Tens of Year 80	18	P_r + 7.8 ms	27	P_r + 8.8 ms	36	P_r + 9.8 ms
Position Ident. (P_7)	P_r + 6.9 ms	Position Ident. (P_8)	P_r + 7.9 ms	Position Ident. (P_9)	P_r + 8.9 ms	Position Ident. (P_0)	P_r + 9.9 ms

Note 1: The BIT Time is the time of the BIT leading edge and refers to the leading edge of P_r.

TABLE 6-16. IRIG-G CONTROL BIT ASSIGNMENT FOR YEAR INFORMATION			
POS. ID	**CTRL BIT NO**	**DESIGNATION**	**EXPLANATION**
P0 to P5 is BCD Time-of-Year in seconds, Minutes, Hours, Days and Fraction of seconds			
P49	-	P6	Position Identifier # 6
P50	1	Year, BCD 1	Last 2 digits of year in BCD
P51	2	Year, BCD 2	IBID
P52	3	Year, BCD 4	IBID
P53	4	Year, BCD 8	IBID
P54	5	Not Used	Unassigned
P55	6	Year, BCD 10	Last 2 digits of year in BCD
P56	7	Year, BCD 20	IBID
P57	8	Year, BCD 40	IBID
P58	9	Year, BCD 80	IBID
P59	--	P7	Position Identifier # 7
P60	10	Not Used	Unassigned
P61	11	IBID	IBID
P62	12	IBID	IBID
P63	13	IBID	IBID
P64	14	IBID	IBID
P65	15	IBID	IBID
P66	16	IBID	IBID
P67	17	IBID	IBID
P68	18	IBID	IBID
P69	--	P8	Position Identifier # 8
P7 to P0 are control functions.			
Note 1: The bit Time is the time of the bit leading edge and refers to the leading edge of P_r			

TABLE 6-17. FORMAT G CONTROL FUNCTIONS (36 BITS)							
Control Function BIT	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**	**Control Function BIT**	**BIT Time**
1	Units of Year 01 P_r + 6.0 ms	10	P_r + 7.0 ms	19	P_r + 8.0 ms	28	P_r + 9.0 ms
2	Units of Year 02	11	P_r + 7.1 ms	20	P_r + 8.1 ms	29	P_r + 9.1 ms
3	Units of Year 04	12	P_r + 7.2 ms	21	P_r + 8.2 ms	30	P_r + 9.2 ms
4	Units of Year 08	13	P_r + 7.3 ms	22	P_r + 8.3 ms	31	P_r + 9.3 ms
5	P_r + 6.4 ms	14	P_r + 7.4 ms	23	P_r + 8.4 ms	32	P_r + 9.4 ms
6	Tens of Year 10	15	P_r + 7.5 ms	24	P_r + 8.5 ms	33	P_r + 9.5 ms
7	Tens of Year 20	16	P_r + 7.6 ms	25	P_r + 8.6 ms	34	P_r + 9.6 ms
8	Tens of Year 40	17	P_r + 7.7 ms	26	P_r + 8.7 ms	35	P_r + 9.7 ms
9	Tens of Year 80	18	P_r + 7.8 ms	27	P_r + 8.8 ms	36	P_r + 9.8 ms
Position Ident. (P_7)	P_r + 6.9 ms	Position Ident. (P_8)	P_r + 7.9 ms	Position Ident. (P_9)	P_r + 8.9 ms	Position Ident. (P_0)	P_r + 9.9 ms

TABLE 6-18. PARAMETERS FOR FORMAT G	
Pulse Rates	**Pulse Duration**
Bit rate: 10 k pps Position identifier: 1 k pps Reference marker: 100 pps	Index marker: 20 µs Binary zero or unencoded bit: 20 µs Binary one or coded bit: 50 µs Position identifiers: 80 µs Reference bit: 80 µs
Resolution	**Mark-To-Space Ratio**
0.1 ms dc level 10 µs modulated 100 Hz carrier	Nominal value of 10:3 Range of 3:1 to 6:1

6.7 Format H

6.7.1 The beginning of each 1-minute time frame is identified by two consecutive 0.8-second bits, P_0 and P_r. The leading edge of P_r is the on-time reference point for the succeeding time code. Position identifiers P_0 and P_1 through P_5, occur every 10th bit one second before the leading edge of each succeeding 6 ppm on-time bit (see Figure 6-6).

6.7.2 The time code word and the control functions presented during the time frame are pulse width coded. The binary zero and the index markers each have duration of 0.2 seconds, and a binary one has duration of 0.5 seconds. The leading edge is the 1 pps on-time reference point for all bits.

6.7.3 The BCD time-of-year consists of 23 bits beginning at index count 10. The sub-word bits occur between position identifiers P_0 and P_5: 7 for minutes, 6 for hours, and 10 for days to complete the time code word. An index marker occurs between the decimal digits in each sub-word to provide separation for visual resolution. The LSB occurs first. The code recycles yearly. Each bit position is identified in Table 6-19.

6.7.4 Nine control functions occur between position identifiers P_5 and P_0. Any control function bit or combination of bits can be programmed to read a binary one or zero during any specified number of time frames.

6.7.5 Details of the IRIG Format H parameters are shown at Table 6-20.

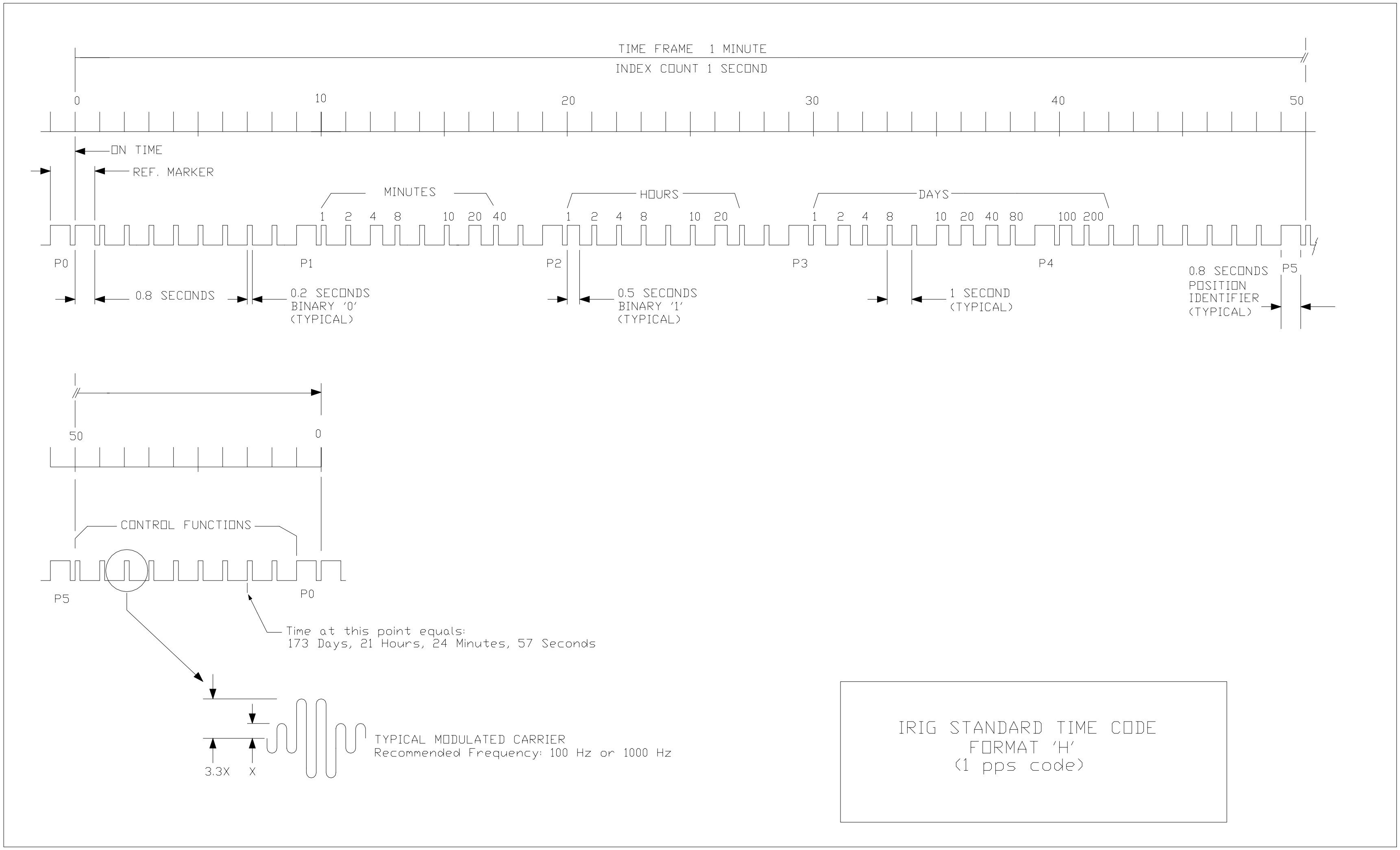

Figure 6-6. Format H: BCD time-of-year in days, hours, minutes, and control bits.

TABLE 6-19. FORMAT H, SIGNAL H001

BCD TIME-OF-YEAR CODE (23 DIGITS)

			MINUTES SUBWORD			**HOURS SUBWORD**			**DAYS SUBWORD**					
BCD Code Digit No.	Subword Digit Wt SECONDS	BIT Time (Note 1)	BCD Code Digit No.	Subword Digit Wt MINUTES	BIT Time	BCD Code Digit No.	Subword Digit Wt HOURS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time	BCD Code Digit No.	Subword Digit Wt DAYS	BIT Time
Reference BIT		P_r	1	1	P_r + 10 sec	8	1	P_r + 20 sec	14	1	P_r + 30 sec	22	100	P_r + 40 sec
Index Marker		P_r + 1 sec	2	2	P_r + 11 sec	9	2	P_r + 21 sec	15	2	P_r + 31 sec	33	200	P_r + 41 sec
Index Marker		P_r + 2 sec	3	4	P_r + 12 sec	10	4	P_r + 22 sec	16	4	P_r + 32 sec	Index Marker		P_r + 42 sec
Index Marker		P_r + 3 sec	4	8	P_r + 13 sec	11	8	P_r + 23 sec	17	8	P_r + 33 sec	Index Marker		P_r + 43 sec
Index Marker		P_r + 4 sec	Index Marker		P_r + 14 sec	Index Marker		P_r + 24 sec	Index Marker		P_r + 34 sec	Index Marker		P_r + 44 sec
Index Marker		P_r + 5 sec	5	10	P_r + 15 sec	12	10	P_r + 25 sec	18	10	P_r + 35 sec	Index Marker		P_r + 45 sec
Index Marker		P_r + 6 sec	6	20	P_r + 16 sec	13	20	P_r + 26 sec	19	20	P_r + 36 sec	Index Marker		P_r + 46 sec
Index Marker		P_r + 7 sec	7	40	P_r + 17 sec	Index Marker		P_r + 27 sec	20	40	P_r + 37 sec	Index Marker		P_r + 47 sec
Index Marker		P_r + 8 sec	Index Marker		P_r + 18 sec	Index Marker		P_r + 28 sec	21	80	P_r + 38 sec	Index Marker		P_r + 48 sec
Position Ident. (P_1)		P_r + 9 sec	Position Ident. (P_2)		P_r + 19 sec	Position Ident. (P_3)		P_r + 29 sec	Position Ident. (P_4)		P_r + 39 sec	Position Ident. (P_5)		P_r + 49 sec

CONTROL FUNCTIONS (9 BITS)

Control Function BIT	**BIT Time**
1	P_r + 50 sec
2	P_r + 51 sec
3	P_r + 52 sec
4	P_r + 53 sec
5	P_r + 54 sec
6	P_r + 55 sec
7	P_r + 56 sec
8	P_r + 57 sec
9	P_r + 58 sec
Position Ident. (P_0)	P_r + 59 sec

Note 1: The BIT Time is the time of the BIT leading edge and refers to the leading edge of P_r.

TABLE 6-20. PARAMETERS FOR FORMAT H	
Pulse Rates	**Pulse Duration**
Bit rate: 1 pps Position identifier: 6 ppm Reference marker: 1 ppm	Index marker: 0.2 s Binary zero or unencoded bit: 0.2 s Binary one or coded bit: 0.5 s Position identifiers: 0.8 s Reference bit: 0.8 s
Resolution	**Mark-To-Space Ratio**
1 s dc level 10 ms modulated 100 Hz carrier 1 ms modulated 1 kHz carrier	Nominal value of 10:3 Range of 3:1 to 6:1

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APPENDIX A

LEAP YEAR/LEAP SECOND CONVENTIONS

1.1 Leap Year Convention

The U.S. Naval Observatory Astronomical Applications Department defines the leap year according to the Gregorian calendar, which was instituted by Pope Gregory VIII in 1582 to keep the year in a cycle with the seasons. The average Gregorian calendar year, technically known as the Tropical Year, is approximately 365.2425 days in length and it will take about 3,326 years before the Gregorian calendar is as much as one day out of step with the seasons.

According to the Gregorian calendar, which is the civil calendar in use today, years that are evenly divisible by 4 are leap years with the exception of century years that are not evenly divisible by 400. This means that years 1700, 1800, 1900, 2100, 2200, and 2500 are NOT leap years and that years 1600, 2000, and 2400 ARE leap years.

Additional information can be found at the following U.S. Naval Observatory web sites.

- http://timeanddate.com/date/leapyear.html
- http://aa.usno.navy.mil/faq/docs/leap_years.html

1.2 Leap Second Convention

Civil time is occasionally adjusted by one-second increments to insure that the difference between a uniform time-scale defined by International Atomic Time (TAI) does not differ from the Earth's rotational time by more than 0.9 seconds. Consequently, Coordinated Universal Time (UTC), also an atomic time, was established in 1972 and is adjusted for the Earth's rotation and forms the basis for civil time.

Twenty two leap seconds have been added to keep UTC in synchronization with the rotation of the earth. In 1980, when the Global Positioning System (GPS) came into being, it was initially synchronized to UTC. However, GPS time does not add leap seconds, and consequently, GPS time is thirteen seconds ahead of UTC. The relationship between (TAI) and UTC is given by a simple accumulation of leap seconds occurring approximately once per year. If required, time changes are made on December 31 and on June 30 at 2400 hours.

At any instant ($_i$), T_i = TAI time,

U_i = UTC time expressed in seconds, and

$T_i = U_i + L_i$

where (L_i) is the accumulated leap second additions between the epoch and the instant ($_i$).

The U.S. Naval Observatory maintains a history of accumulated leap seconds on one of their web sites. The site URL is: ftp://maia.usno.navy.mil/ser7/tai-utc.dat, which provides a list of TAI minus UTC from 1961 to 1999. As of the publication date of this document, the last leap second was in 1999. Additional information can be obtained from the U.S. Naval Observatory's Earth Orientation Department at the following web sites.

- http://maia.usno.navy.mil/eo/leapsec.html
- http://tycho.usno.navy.mil/leapsec.990505.html

APPENDIX B

BCD COUNT/BINARY COUNT

The reader is referred to Table B-1 for the BCD count data and Table B-2 for Binary count Data.

TABLE B-1. BCD COUNT (8n 4n 2n 1n)		
Decimal Number	**n**	**BCD Bits**
1	1	1
5	1	3
10	10	5
15	10	5
150	100	9
1 500	$1x10^3$	13
15 000	$10x10^3$	17
150 000	$100x10^3$	21
1 500 000	$1x10^6$	25
15 000 000	$10x10^6$	29
150 000 000	$100x10^6$	33
1 500 000 000	$1x10^6$	37
15 000 000 000	$10x10^9$	41
150 000 000 000	$100x10^9$	45
1 500 000 000 000	$1x10^{12}$	49
15 000 000 000 000	$10x10^{12}$	53
150 000 000 000 000	$100x10^{12}$	57

TABLE B-2. BINARY COUNT (2^n)			
Decimal Number	**Binary Number**	**Decimal Number**	**Binary Number**
n	**2^n**	**n**	**2^n**
0	1		
1	2	26	67 108 864
2	4	27	134 217 728
3	8	28	268 435 456
4	16	29	536 870 912
5	32	30	1 073 741 824
6	64	31	2 147 483 648
7	128	32	4 294 967 296
8	256	33	8 589 934 592
9	512	34	17 179 869 184
10	1 024	35	34 359 738 368
11	2 048	36	68 719 476 736
12	4 096	37	137 438 953 472
13	8 192	38	274 877 906 944
14	16 384	39	54 9 755 813 888
15	32 768	40	1 099 511 627 776
16	65 536	41	2 199 023 255 552
17	131 072	42	4 398 046 511 104
18	262 144	43	8 796 093 022 208
19	524 288	44	17 592 186 044 416
20	1 048 576	45	35 184 372 088 832
21	2 097 152	46	70 368 744 177 664
22	4 194 304	47	140 737 488 355 328
23	8 388 608	48	281 474 976 710 656
24	16 777 216	49	562 949 953 421 312
25	33 554 432	50	1 125 899 906 842 620

APPENDIX C

HARDWARE DESIGN CONSIDERATIONS

TABLE C-1. TIME CODE GENERATOR HARDWARE MINIMUM DESIGN CONSIDERATIONS

Code	Level (dc) Pulse Rise Time Between the 10 and 90% Amplitude Points	Jitter Modulated at Carrier Frequency	Jitter Level (dc) Pulse-to-Pulse
Format A	≤ 200 ns	≤1%	≤100 ns
Format B	≤ 1 µs	≤1%	≤200 ns
Format D	≤ 1 µs	≤1%	≤200 ns
Format E	≤ 1 µs	≤ 1%	≤200 ns
Format G	≤ 20 ns	≤ 1%	≤ 20 ns
Format H	≤ 1 µs	≤1%	≤200 ns

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GLOSSARY

1.1 Definitions of Terms And Usage

Accuracy - Systematic uncertainty (deviation) of a measured value with respect to a standard reference.

Binary Coded Decimal (BCD) - A numbering system which uses decimal digits encoded in a binary representation (1n 2n 4n 8n) where n=1, 10, 100, 1 k, 10 k...N (see appendix B).

Binary numbering system (Straight Binary) - A numbering system which has two as its base and uses two symbols, usually denoted by 0 and 1 (see appendix B).

BIT (B(INARY + DIG)IT - An abbreviation of binary or binary-coded decimal digits which forms each sub-word and which determines the granularity or resolution of the time code word.

Frame rate - The repetition rate of the time code.

Index count - The number that identifies a specific bit position with respect to a reference marker.

Index markers - Uuencoded, periodic, interpolating bits in the time code.

Instrumentation Timing - A parameter serving as the fundamental variable in terms of which data may be correlated.

Leap second - See appendix A.

Leap year - See appendix A.

On-time - The state of any bit being coincident with a Standard Time Reference (U.S. Naval Observatory or National Bureau of Standards or other national laboratory).

On-time reference marker - The leading edge of the reference bit P_r of each time frame.

Position identifier - A particular bit denoting the position of a portion or all of a time code.

Precision - An agreement of measurement with respect to a defined value.

Reference marker - A periodic combination of bits, which establishes that instant of time, defined by the time code word.

Resolution (of a time code) - The smallest increment of time or least significant bit that can be defined by a time code word or sub-word.

Second - Basic unit of time or time interval in the International System of Units (SI) which is equal to 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of Cesium 133.

Subword - A subdivision of the time code word containing only one type of time unit, for example, days, hours, seconds or milliseconds.

Time - Signifies epoch, i.e., the designation of an instant of time on a selected time scale such as astronomical, atomic or UTC.

Time code -- A system of symbols used for identifying specific instants of time.

Time Code Word - A specific set of time code symbols that identifies one instant of time. A time code word may be subdivided into sub-words.

Time Frame - The time interval between consecutive reference markers that contains all the bits that determine the time code format.

Time Interval - The duration between two instants read on the same time scale, usually expressed in seconds or in a multiple or sub multiple of a second.

Time Reference - The basic repetition rate chosen as the common time reference for all instrumentation timing (usually 1 pps).

Time T_0 - The initial time $0^h\ 0^m\ 0^s$, January 1, or the beginning of an epoch.

1.2 Time-related terms and the relationship between the various time scales.

Coordinated Universal Time (UTC) - is maintained by the Bureau International de l'Heure (BIH) which forms the basis of a coordinated dissemination of standard frequencies and time signals. A UTC clock has the same rate as a TAI clock, but differs by an integral number of seconds. The step-time adjustments are called "leap seconds." Leap seconds are subtracted or added to UTC to keep in synchronism with UT1 to within ± 0.9 seconds (see appendix A).

DUT1 - is the predicted difference between UT1 and UTC and is given by DUT1 = UT1-UTC.

Ephemeris Time (ET) - is obtained from observations of the motion of the moon about the earth.

Epoch - signifies the beginning of an event.

International Atomic Time (TAI) - is an atomic time scale based on data from a worldwide set of clocks and is the internationally agreed to time reference. The TAI is maintained by the BIH, Paris, France. Its epoch was set such that TAI was in approximate agreement with UT1 on 1 January 1958.

International Atomic Time (TAI) time code - represents a binary count of elapsed time in seconds since the 1 January 1958 epoch. The Bureau International de l'Heure (BIH), the U.S. Naval Observatory (USNO), and other national observatories and laboratories maintain this count which accumulates at 86,400 seconds per day.

Sidereal time - is determined and defined by observations of the earth with respect to the stars. A mean sidereal day is approximately $23^h\ 56^m\ 4.09^s$. A solar year contains 366.24 sidereal days.

Solar time - is based on the rotation of the earth about the sun.

Time scale - is a reference system for specifying occurrences with respect to time.

Universal time (UT) - is the mean solar time of the prime meridian plus 12h, determined by measuring the angular position of the earth about its axis. The UT is sometimes designated Greenwich Mean Time (GMT), but this designation should be avoided. The official U.S. Naval Observatory designation is UT(USNO)

UT0 - measures UT with respect to the observer's meridian (position on earth) that varies because of the conical motion of the poles.

UT1 - is UT0 corrected for variations in the polar motion and is proportional to the rotation of the earth in space. In its monthly bulletin, Circular-D, the Bureau International de l'Heure (BIH) publishes the current values of UT1 with respect to International Atomic Time (TAI).

UT2 - is UT1 corrected empirically for annual and semiannual variations of the rotation rate of the earth. The maximum correction is about 30 ms.

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Anexo II

Documentación receptor GPS

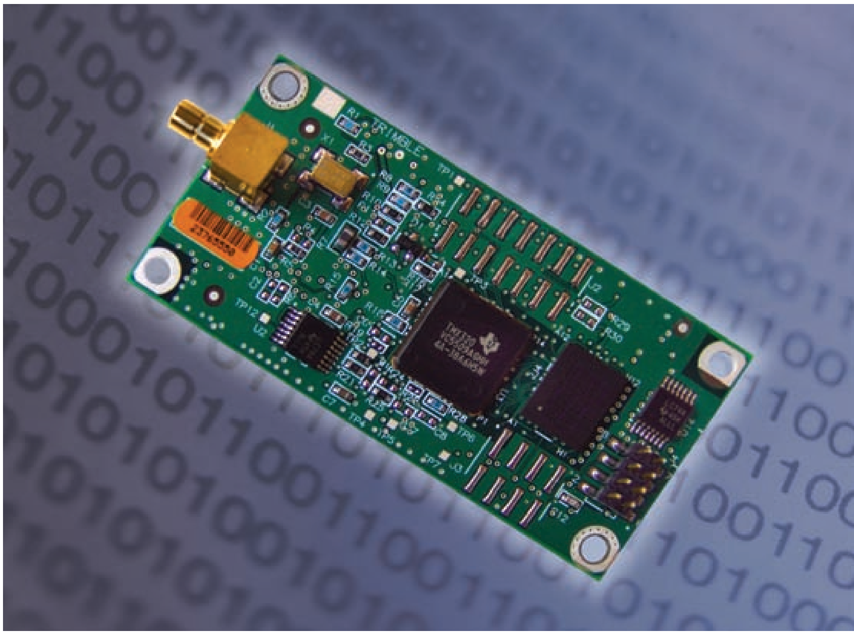
Resolution T

Full-featured, low-cost, embedded GPS Timing Receiver

Key Features and Benefits

- **RoHS compliant**
- **Automatic self-survey for improved timing accuracy.**
- **Extremely accurate 1-PPS output, synchronized to GPS or UTC within 15 ns (one sigma)**
- **Cable delay compensation removes time delay due to cable distance between antenna and receiver**
- **TRAIM - Timing Receiver Autonomous Integrity Monitoring assures high PPS integrity**
- **Quantization Error Reporting can further improve native accuracy**
- **Supports 3 V or 5 V Antennas**

Trimble's Resolution T™ GPS Timing Receiver is a significant new development in GPS architecture: the general purpose, DSP-based software GPS timing receiver. The development of Trimble DSP/GPS software was key to this accomplishment.



The Resolution T GPS Timing Receiver

Precise Timing Where You Need It

The receiver is an all-in-view, 12-channel, parallel-tracking, embeddable GPS receiver designed to provide precise GPS or UTC time and synchronization for many static timing applications. The timing accuracy will provide for your current needs with plenty of headroom for future requirements.

This low-cost, yet highly accurate and reliable receiver allows the system integrator to put precise timing and synchronization into locations where cost or size is a limitation. Rather than sharing time from a single timing source, with the resultant delays and loss of accuracy, you now can have precise time (synchronization) at every location regardless of how isolated or remote.

Features Flexibility with Software

To provide a true software-driven GPS timing receiver, the Resolution T receiver uses an off-the-shelf, software programmable, general-purpose, digital signal processor (DSP) in place of the usual custom GPS ASIC. Using a general-purpose DSP allows incremental software improvements to be implemented throughout the product life cycle. This is not possible in custom GPS hardware ASICs, because most features are permanently locked in the hardware design. The Resolution T receiver can be updated easily in the field with new features as they become available. The modular design also allows for both reduced integration time and low implementation risk.

1-PPS within 15 ns

The Resolution T receiver outputs a 1 Pulse-per-second (1 PPS) timing signal accurate to within 15 nanoseconds of GPS or UTC (1 sigma) when using an overdetermined solution in a stationary mode.

3 or 5 Volt Antenna Compatible

The receiver is designed for 3.3-VDC prime power, but provides a separate pin on the I/O connector for powering the antenna with a user-supplied voltage from 3.0 to 5.5 VDC.

Starter Kit

The Resolution T Starter Kit provides everything you need to start integrating the module into your application. The kit includes an active, external 5-VDC Bullet-style antenna, 50 feet of RG-59 cable, and an AC/DC power adapter. The starter kit enclosure includes a mother board that provides serial output, and a serial interface cable. A reference manual and monitor programs are provided on CD-ROM.

Resolution T

Full-featured, low-cost, embedded GPS Timing Receiver

PERFORMANCE SPECIFICATIONS

General	L1 (1575.42 MHz) Frequency, C/A Code, 12-channel, parallel-tracking receiver, DSP-based	
Update Rate	TSIP @ 1 Hz; NMEA @ 1 HZ	
Accuracy	Horizontal Position:	<6 meters (50%), <9 meters (90%)
	Altitude Position:	<11 meters (50%), <18 meters (90%)
	Velocity:	0.06 m/sec
	PPS:	within 15 ns to GPS/UTC (1 Sigma) <5 ns with quantization error removed
Acquisition	Reacquisition:	<2 sec. (90%)
	Hot Start:	<14 sec (50%), <18 sec (90%)
	Warm Start:	<41 sec (50%), <45 sec (90%)
	Cold Start:	<46 sec (50%), <50 sec (90%)

Cold start requires no initialization. Warm start implies last position, time and almanac are saved by backup power. Hot start implies ephemeris also saved. Hot and Warm are shown for comparison purposes and are not used in timing applications.

Sensitivity	Acquisition	–136 dBm
	Tracking	–141 dBm
Operational (COCOM) Limits	Altitude	18,000 m
	Velocity	515 m/s

Either limit may be exceeded, but not both

PHYSICAL CHARACTERISTICS

Dimensions	66.3mm L x 32.1mm W x 8.5mm H (2.6"L x 1.3"W x 0.33"H)
Weight	approximately 12.5 grams (0.4 ounce)

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	–40° C to +85° C	
Storage Temperature	–55° C to +105° C	
Vibration	0.008 g^2/Hz	5 Hz to 20 Hz
	0.05 g^2/Hz	20 Hz to 100 Hz
	–3 dB/octave	100 Hz to 900 Hz
Operating Humidity	5% to 95% R.H. non-condensing, at +60° C	
Altitude	–400 to 18,000 m max	

ELECTRICAL SPECIFICATIONS

Prime Power	+3.3 VDC ±0.3 VDC
Power Consumption	GPS board only: 350 mW @ 3.3 V
Ripple Noise	Max 50 mV, peak to peak from 1 Hz to 1 MHz
Antenna Fault Protection	Short-circuit/open detection and protection

INTERFACE CHARACTERISTICS

Connectors	I/O:	8-pin (2x4) 2 mm Male Header
	RF:	Right-angle SMB (SMA optional)
Serial Port		1 serial port (transmit/receive)
PPS		3.3 V CMOS-compatible TTL-level pulse, once per second Rising edge of the pulse synchronized with GPS/UTC
Protocols		TSIP @ 9600 baud, 8 bits NMEA 0183 v3.0 @ 4800 baud, 8 bits
NMEA Messages		GGA, VTG, GLL, ZDA, GSA, GSV and RMC Messages selectable by TSIP command Selection stored in flash memory

ACCESSORIES

Rooftop Antenna	Bullet III, TNC (F) 3.3 VDC with 30 dBi gain. or Bullet III, F 5 VDC with 35 dBi gain
Transition cable	SMB to F
Rooftop Antenna Kits	3 or 5 VDC

FOR MORE INFORMATION

E-mail us at: timing@trimble.com
Visit our website at http://www.trimble.com/restime

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RESOLUTION T

SYSTEM DESIGNER REFERENCE MANUAL

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TABLE OF CONTENTS

ABOUT THIS MANUAL

This System Designer's Reference Manual describes how to integrate and operate the Resolution T® GPS timing receiver. The instructions in this manual assume that you know how to use the primary functions of Microsoft Windows.

If you are not familiar with GPS, visit Trimble's website, www.trimble.com, for an interactive look at Trimble and GPS.

Technical Assistance

If you cannot locate the information you need in this product documentation, contact the Trimble Technical Assistance Center at 800-767-4822.

CHAPTER

1

STARTER KIT

In this chapter:

- Product Overview
- Starter Kit
- Timing Receiver Performance
- Interface Protocols
- Ordering Starter Kit Components
- Starter Kit Interface Unit
- Power
- Hardware Setup
- Software Toolkit

PRODUCT OVERVIEW

The Trimble Resolution T embedded timing board, is a full featured, 12 channel, parallel tracking GPS receiver. The receiver is designed to operate on the L1 (1575.42 MHz) frequency, providing standard position service (SPS) using Coarse Acquisition (C/A) code. It features an off-the-shelf, low cost, software programmable general purpose Digital Signal Processor (DSP) instead of a custom GPS ASIC.

The Trimble Resolution T is designed for 3.3V prime power and provides a separate pin on the I/O connector for powering the antenna with a user supplied voltage from 3.0V to 5.5V (antenna dependent).

Timing Features

The Resolution T timing features include:

- Automatic Self Survey
- Overdetermined Timing Mode
- Single Satellite Timing Mode
- Timing Super Packets
- TRAIM
- Position Integrity
- Cable Delay Compensation
- Accuracy <15 ns (1 sigma).

Basic Operation

The Resolution T automatically initiates a self-survey upon acquisition of GPS satellites. When the survey is completed, the receiver switches into the Overdetermined Timing Mode. In this mode, the reference position from the self survey is maintained in memory and the receiver solves only for clock error and clock bias. The receiver provides for both Position and Time Receiver Autonomous Integrity Monitoring which allows the receiver to self determine a position change or to remove a satellite providing incorrect information from the timing solution.

NOTE: To offset the delay inherent in the RF cable from the antenna to the receiver and further improve the accuracy, determine the length of the cable and enter the offset based on the specific cable type.

Starter Kit

The Starter Kit makes it simple to evaluate the Resolution T receiver performance. The Starter Kit can be used as a platform for configuring the receiver software or as platform for troubleshooting your design. The Starter Kit includes the Resolution T timing module mounted on an interface motherboard in a durable metal enclosure. The motherboard accepts 9 - 32 VDC power and provides regulated +3.3V power to the Resolution T receiver. The motherboard also contains:

- 3.6V lithium battery that provides back-up power to the receiver.
- Circuitry to convert the CMOS output to RS-232, enabling the user to connect the RS-232 port in the Starter Kit to the PC COM port via an RS-232 cable connection.
  - 35 dB, 5.5 VDC Bullet III Rooftop GPS Antenna (F)
  - 50’ R59 antenna cable terminated with F connectors
  - 9-pin RS-232 interface cable.
  - AC/DC power supply adapter (input: 100-240VAC, output: 12 VDC).
  - SMB to F adapter cable.
  - CD containing software tools used to communicate with the receiver, the System Designer Reference Manual, and the DSP Monitor Program.

REMOVING THE RESOLUTION T MODULE

The Resolution T GPS receiver is secured to the motherboard standoffs with Phillips head screws, allowing for removal and integration with the user's application. Follow these steps to remove the receiver from the motherboard:

- Disconnect power to the enclosure.
- Remove base plate and unplug the RF cable from the receiver.
- Use a small Phillips headed screw driver to remove the securing hardware which holds the Resolution T GPS receiver to the motherboard.
- Gently rock the board loose from the motherboard I/O connector.

Warning: Before opening the interface unit, disconnect the unit from any external power source and confirm that both you and your work surface are properly grounded for ESD protection. The interface unit motherboard contains a 3.6 VDC lithium battery.

The Resolution T is designed for embedded applications. The digital I/O lines and power lines are not designed with additional ESD protection like a stand-alone receiver would be. Use standard CMOS ESD handling precautions when removing and installing the receiver module.

TIMING RECEIVER PERFORMANCE

The Resolution T GPS timing receiver is a complete 12-channel, parallel tracking, GPS receiver, designed to operate with the L1 frequency, Standard Position Service, Coarse Acquisition code. Using the Trimble Colossus RF Downconverter and Texas Instruments 5509 series General Purpose DSP, the receiver is designed in a single board format, specially adapted for timing applications where reliability, performance, and ease of integration are desired. The receiver features Trimble's improved signal processing code, a high-gain RF section for compatibility with standard active gain GPS antennas, and a CMOS level pulse-per-second (PPS) output for timing and synchronization applications.

Timing applications are assumed to be static. The special timing software used with the Resolution T receiver configures the unit into an automatic self survey mode at start up. The receiver will average position fixes for a specified time (one per second) and at the end of this period will save this reference location. At this time the receiver will go into an Overdetermined Clock mode and no longer solve for position but only for clock error and clock bias using all of the available satellites. This provides an accuracy of less than 15ns (1 Sigma) for the 1PPS output.

User settings such as port parameters and NMEA settings can be stored in the receiver’s non-volatile (Flash) memory. These settings are retained without main power or battery back-up power applied. The Resolution T receiver has a single configurable serial I/O communication port.

NOTE: When customizing port assignments or characteristics, confirm that your changes do not affect your ability to communicate with the receiver.

INTERFACE PROTOCOLS

The Resolution T receiver operates using one of two protocols—Trimble Standard Interface Protocol (TSIP) or NMEA 0183. The factory default setting for the I/O port is TSIP bi-directional. Protocol selection and port characteristics are user configurable.

TSIP

TSIP (Trimble Standard Interface Protocol) is a powerful binary packet protocol that allows the system designer maximum configuration control over the GPS receiver for optimum performance in timing applications. TSIP supports multiple commands and their associated response packets for use in configuring the Resolution T receiver to meet user requirements.

NMEA

NMEA 0183 (National Marine Electronics Association) is an industry standard protocol common to marine applications. NMEA provides direct compatibility with other NMEA-capable devices such as chart plotters, radar, etc. The Resolution T receiver supports the ZDA NMEA message for GPS timing. Other NMEA messages and output rates can be user selected as required.

ORDERING STARTER KIT COMPONENTS

The Resolution T GPS receiver is available in a Starter Kit or as an individual receiver and associated antenna. The Starter Kit includes all the components necessary to quickly test and integrate the receiver:

- SMB to F, RG213 antenna transition cable.
- AC/DC power supply adapter.
- DC Power cable (3-wire).
- RS-232 interface cable DB9M/DB9F (pin to pin).
- 50' RG59 rooftop antenna cable (F to F).
- CD-ROM containing the Trimble Standard Interface Protocol (TSIP) for Resolution T, the System Designer Reference Manual, and the DSP_Monitor software.

The following table provides ordering information for the Resolution T GPS receiver and the associated antennas and cables.

Product	**Part Number**
Resolution T GPS timing receiver	52664-00
Resolution T GPS receiver Starter Kit	53188-00
Antenna transition cable RG213 SMB-F	22806
Bullet III 5.5 VDC rooftop Antenna (F type)	41556-00
50' RG59 Rooftop antenna cable	23420
RS-232 interface cable DB9M/DB9F	19309-00
Power cable	20260

Table 1: Ordering Products

NOTE: Part numbers are subject to change. Confirm part numbers with your Trimble representative when placing your order. Other rooftop cables and antenna combinations are also available.

STARTER KIT INTERFACE UNIT

The Starter Kit interface unit consists of a Resolution T GPS receiver attached to an interface motherboard, housed in a sturdy metal enclosure. This packaging simplifies evaluation and software development with the receiver by providing an RS-232 serial interface which is compatible with most PC communication ports. Power (9-32 VDC) is supplied through the power connector on the front of the interface unit. The motherboard features a switching power supply which converts this voltage input to the 3.3 volts required by the receiver and the 5 volts required by the antenna. The DB9 connector allows for an easy connection to a PC serial port using the serial interface cable provided in the Starter Kit. The metal enclosure protects the receiver and the motherboard for testing outside of the laboratory environment.

The Resolution T GPS receiver, installed in the Starter Kit interface unit, is a single port receiver. A straight-in, panel-mount RF SMB connector supports the GPS antenna connection. The center conductor of the SMB connector also supplies +5.5 VDC for the Low Noise Amplifier of the active antenna. (Note: A 3.3VDC antenna can also be supported) On the Resolution T GPS receiver, an 8-pin (2x4), 2 mm header (J4) supports the serial interface (CMOS level), the pulse-per-second (PPS) signal (CMOS level), and the input power (+3.3 VDC). Figure 1 illustrates the receiver in the metal enclosure.

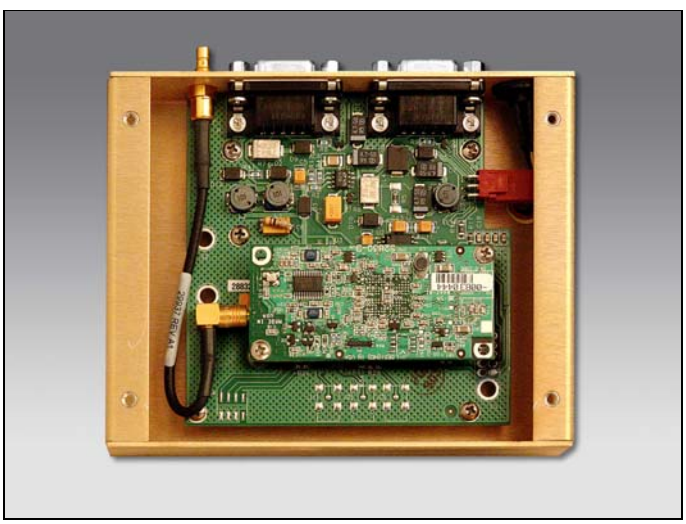


Figure 1—GPS Receiver in Enclosure

The interface motherboard includes a 9 to 32 VDC switching power supply which provides regulated +3.3 VDC power to the receiver, regulated +5 VDC power to the antenna, and contains circuitry which provides an RS-232 interface to a computer. The CMOS level PPS is brought directly out to Pin 9 of the Port 2 DB9 connector on the front of the interface unit.

The Starter Kit includes an AC/DC converter for powering the module from an AC wall socket. The metal enclosure (see Figure 2) provides 2 DB9 interface port connectors, an antenna connector, and a power connector. Port 1 on the metal enclosure is for serial I/O; port 2 is for PPS only.

Figure 2—Starter Kit Interface Unit

The mounting plate is secured to the metal enclosure with four screws. The eight pin I/O header on the receiver module connects directly to the motherboard. Figure 2 illustrates the Starter Kit interface unit.

Serial Port Interface

The Starter Kit interface unit is a DCE (Data Communication Equipment) device. To connect to a host computer, or DTE (Data Terminal Equipment) device, use a straight through cable. To connect a Differential Radio (DCE device) to the receiver (DCE Device) use a cross over cable or null modem cable

Pin	Description
1	NC
2	TX
3	RX
4	NC
5	GND
6	NC
7	NC
8	NC
9	NC

Table 2: Port 1 Pinouts

Pin	Description
1	NC
2	NC
3	NC
4	NC
5	GND
6	NC
7	NC
8	NC
9	PPS Out

Table 3: Port 2 Pinouts

Pulse-Per-Second (PPS)

The receiver provides a 1.0 millisecond wide, CMOS compatible Pulse-Per-Second (PPS). The PPS is a positive pulse available on pin 9 of the port 2 DB9 connector of the interface unit (see Table 3). The rising edge of the pulse is synchronized to GPS. The timing accuracy is <15 nanoseconds (1 σ) when operating in the Overdetermined Timing Mode. The rising edge of the pulse is less than 20 nanoseconds. The PPS is capable of driving a load up to 5mA without damaging the receiver.

The PPS signal is defaulted to always output. This is a customer selectable feature under TSIP packet 8F-4E. Other options include PPS output when one or more satellites are useable or when three or more satellites are useable. Additionally, the PPS output can be programmed to provide an Even Second output using TSIP packet 8F-4E.

POWER

The Resolution T GPS receiver is designed for embedded applications and requires a regulated +3.3 VDC input (+3.0 to +3.6 VDC). The receiver provided in the Starter Kit is installed on a motherboard, which provides a DC power regulator which converts a 9 to 32 VDC input to the regulated 3.3 VDC required by the receiver and the regulated 5 VDC required by the antenna. Power can be applied to the interface unit using one of two options: the DC power cable, or the AC/DC power converter.

DC Power Cable

The DC power cable is ideal for bench-top testing environments. The power cable is terminated at one end with a 3-pin plastic connector which mates with the power connector on the metal enclosure. The un-terminated end of the cable provides easy connection to a DC power supply. Connect the red power lead to a source of DC positive +9 to +32 VDC, and connect the black power lead to ground. This connection supplies power to both the receiver and the antenna. The yellow wire of the DC power cable is not used. Battery back-up power is provided by a factory installed 3.6V lithium battery on the motherboard.

Figure 3—DC Power Cable

NOTE: To ensure compliance with CE conducted emissions requirements when using the DC power cable, the Starter Kit interface unit must be bonded to a ground plane.

AC/DC Power Converter

The AC/DC power converter may be used as an alternate power source for the interface unit. The AC/DC power converter converts 110 or 220 VAC to a regulated 12 VDC compatible with the interface unit. The AC/DC power converter output cable is terminated with a 3-pin connector compatible with the power connector on the metal enclosure. The AC power cable is not provided in the kit, since this cable can be country-specific. The input connector is a standard 3-prong connector used on many desktop PCs.

Figure 4—DC Power Converter

HARDWARE SETUP

The Resolution T GPS receiver supports the TSIP or NMEA protocols. A single port supports either the input/output of TSIP messages or the output of NMEA messages. Follow the steps below to setup the Starter Kit interface unit. Figure 5 illustrates the setup.

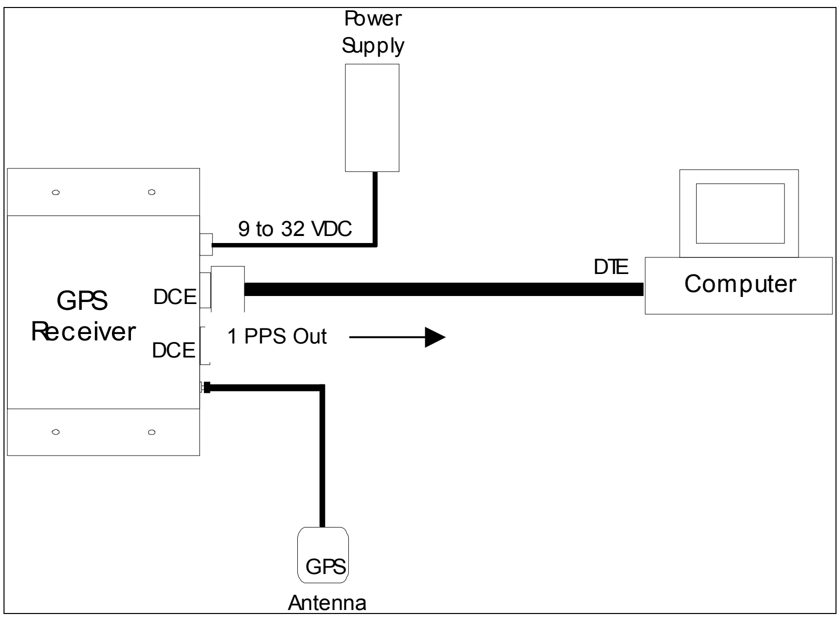


Figure 5—Starter Kit Interface Unit

- When using the TSIP protocol, connect one end of the 9-pin serial interface cable to Port 1 of the interface unit. Connect the other end of the cable to COM1 or COM2 on a PC. A 9-pin-to-25-pin adapter may be required for the serial interface connection to a PC, if your PC has a 25-pin communication port.
- Connect the antenna cable to the interface unit. This connection is made by attaching the antenna cable connector onto the SMB connector on the module. Place the antenna so that it has a clear (180) view of the sky. A reduced number of satellites will be available if this direct view is obstructed.
- Using either the DC power cable or an AC/DC power converter, connect to the 3-pin power connector on the interface unit.
  - DC Power Cable — Connect the terminated end of the power cable to the power connector on the interface unit. Connect the red lead to DC positive voltage (+9 to +32 VDC) and black power lead to DC ground. The yellow wire is not used. Switch on the DC power source.
  - AC/DC Power Converter — Connect the output cable of the converter to the 3-pin power connector on the interface unit. Using the appropriate 3-prong AC power cable (not provided), connect the converter to an AC wall socket (110 VAC or 220 VAC). The AC power cable is not provided in the Starter Kit.

SOFTWARE TOOLKIT

The CD provided in the Starter Kit contains the DSP Monitor program used to monitor GPS performance and to assist system integrators in developing a software interface for the GPS module. DSP Monitor runs on the Windows 95/98/2000/XP platforms.

Following are quick start instructions for using the DSP Monitor application to monitor the receiver's performance.

- Connect one end of the serial interface cable to Port 1 of the interface unit. Connect the other end of the cable to the COM port of your PC.
- Turn on the DC power source or plug in the AC/DC converter.
- Insert the CD in the computer's CD-ROM drive.
- The Monitor program, DSPMon.exe, must be copied onto your computer's hard drive.
- Right-click in the bottom right of the DSP monitor screen to specify the communications port and protocol.
- When the DSP_Monitor screen appears, the TX and RX indicators appear in the lower left corner of the status bar. A blinking TX indicates that the PC is transmitting commands to the receiver; a blinking RX indicates that the PC is receiving reports from the receiver. If either of these indicators stop blinking, there is no activity. The PC COM port settings appear in the lower right corner of this same status bar.
- After a GPS antenna is connected to the receiver, the self survey is complete, and the receiver has achieved a position fix, the following information will display:
  - position
  - time
  - satellites tracked
  - GPS receiver status

NOTES: The receiver also sends a health report every few seconds, even if satellites are not being tracked.

If the DSP Monitor program displays a question mark (?) in a data field, the receiver has not reported a status for this field. If a (?) remains in the data field, the GPS module may not be communicating with the computer. Re-check the interface cable connections and verify the serial port selection and settings. If the communication failure, please call the Trimble Technical Assistance Center (TAC) at 1 (800) 767-4822.

CHAPTER

2

HARDWARE INTEGRATION

In this chapter:

- General Description
- Connectors
- Power Requirements
- Serial Interface
- Pulse-Per-Second
- Mounting
- GPS Antenna

GENERAL DESCRIPTION

Trimble's new Resolution T GPS timing receiver delivers accurate timing solutions for use in all applications where precision timing is needed.

The Resolution T GPS timing receiver is packaged in a small form factor. It typically requires 350 mW of power (at 3.3 VDC). The receiver includes flash memory for field upgrades and for storing the user configuration.

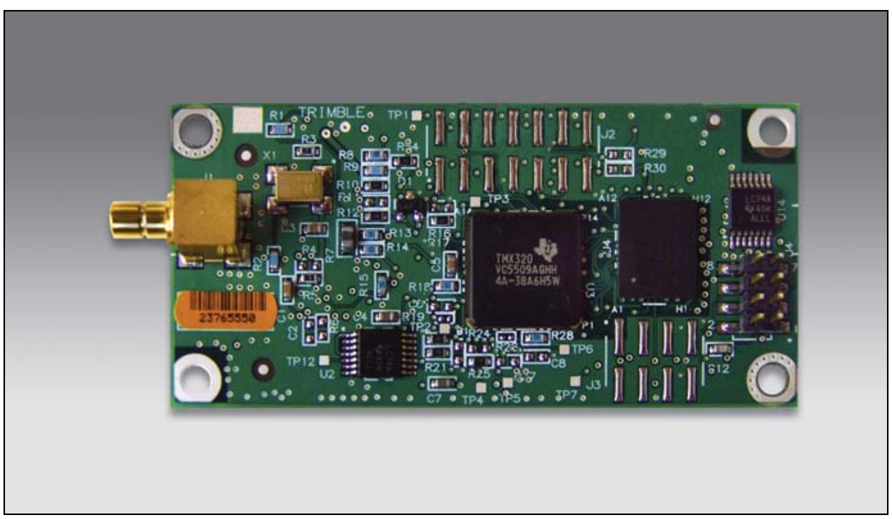


Figure 6—Resolution T Board

CONNECTORS

Digital IO/Power Connector

The Resolution T GPS receiver uses a single 8-pin (2x4) male header connector for both power and data I/O. The power and I/O connector, J4, is a surface mount micro terminal strip. This connector uses 0.126 inch (3.2 mm) high pins on 0.079 inch (2 mm) spacing. The manufacturer of this connector is Samtec, part number TMM-104-01-T-D-SM.

Mating Connectors

A surface mount mating connector from those specified by Samtec as compatible to Samtec TMM-104-01-T-D-SM is recommended.

RF Connector

The RF connector mounted on the Resolution T receiver is a right angle SMB.

Antenna Options

Trimble offers either a 3.3 VDC or a 5.0 VDC rooftop antenna and cable for use with the Resolution T GPS receiver.

Digital IO/Power Connector Pin-out

The Digital IO/Power connector pin-out information is provided in the table below.

Pin Number	Function	Description
1	Antenna Power Input	3.0VDC to 5.5VDC, 55mA max
2	Prime Power Input	+3.3VDC ±0.3VDC
3	TXD A	Port A transmit, CMOS
4	Backup Power Input	Reserved
5	RXD A	Port A receive, CMOS
6	1 PPS	One Pulse-Per-Second, CMOS
7	No Connect	Not used
8	GND	Ground, Power and Signal

Table 4: J4 I/O Connector Signals

POWER REQUIREMENTS

The Resolution T GPS receiver requires +3.3 VDC ±0.3 VDC at 110 mA, typical excluding the antenna. The on-board capacitance is approximately 65 µF. An important design consideration for power is the receiver's internal clock frequency at 12.504 MHz ± 3 KHz. Interference spurs on prime power in this narrow frequency band should be kept to less than 1mV.

The receiver does not require any special power up or down sequencing. The receiver power is supplied through pin 2 of the I/O connector. See Table 5 for the power specifications.

Warning: The Resolution T GPS receiver is ready to accept TSIP commands approximately 2.1 seconds after power -up. If a command is sent to the receiver within this 2.1 second window, the receiver will ignore the command. The Resolution T GPS receiver will not respond to commands sent within the 2.1 second window and will discard any associated command data.

Signal	Voltage	Current	J4 Pin #
VCC	3.0 – 3.6	110mA	2
Ground	0	--	8

Table 5: Power Requirements

SERIAL INTERFACE

The Resolution T GPS receiver provides direct CMOS compatible serial I/O. The RX and TX signals on the J4 I/O connector are driven directly by the UART on the Resolution T GPS receiver. Interfacing these signals directly to a UART in your application circuitry provides direct serial communication without the complication of RS-232 or RS-422 line drivers.

NOTE: The serial I/O signals on J4 are CMOS level. They are not inverted or driven to RS-232 levels.

PULSE-PER-SECOND (PPS)

The Resolution T GPS timing receiver provides a one millisecond wide, CMOS compatible Pulse-Per-Second (PPS). The PPS is a positive pulse available on pin 6 of the power and I/O connector. The rising edge of the PPS pulse is synchronized with respect to UTC. The timing accuracy is within 15 nanoseconds (1σ) to UTC when valid position fixes are being reported in the Overdetermined Mode.

The rising edge of the pulse is typically less than 20 nanoseconds. The distributed impedance of the attached signal line and input circuit can affect the pulse shape and rise time. The PPS can drive a load up to 5mA without damaging the receiver.

MOUNTING

There are four mounting holes at the corners of the PCB that accept 3/16” hex or round standoffs with a 3/8” height, and #4-40 or M3 mounting screws. Space constrained environments may require a different standoff.

GPS ANTENNA

Trimble offers a 3.3 VDC or 5.0 VDC Bullet III rooftop antenna for use with the Resolution T GPS receiver . The antenna receives the GPS satellite signals and passes them to the receiver. The GPS signals are spread spectrum signals in the 1575 MHz range and do not penetrate conductive or opaque surfaces. Therefore, the antenna must be located outdoors with a clear view of the sky. The Resolution T GPS receiver requires an ***active*** antenna. The received GPS signals are very low power, approximately -130 dBm, at the surface of the earth. Trimble's active antenna includes a preamplifier that filters and amplifies the GPS signals before delivery to the receiver.

Figure 7—Bullet III Antenna

CHAPTER

3

SOFTWARE INTERFACE

In this chapter:

- Start-up
- Communicating with the Receiver
- Port Protocol and Data Output Options

START-UP

The Resolution T GPS timing receiver is a complete 12-channel parallel tracking GPS timing receiver designed to operate with the L1 frequency, standard position service, Coarse Acquisition code. When connected to an external GPS antenna, the receiver contains all the circuitry necessary to automatically acquire GPS satellite signals, track up to 12 GPS satellites, and compute location, speed, heading, and time. At power-up the receiver will begin a self-survey process. Upon completion, the receiver will provide an overdetermined timing solution.

The first time the receiver is powered-up, it is searching for satellites from a cold start (no almanac, time, ephemeris, or stored position). While the receiver will begin to compute position solutions within the first 46 seconds, the receiver must continuously track satellites for approximately 15 minutes to download a complete almanac and ephemeris. This initialization process should not be interrupted. The receiver will respond to commands almost immediately after power-up (see Warning below).

Warning:	The Resolution T GPS receiver is ready to accept TSIP commands approximately 2.1 seconds after power -up. If a command is sent to the receiver within this 2.1 second window, the receiver will ignore the command. The Resolution T GPS receiver will not respond to commands sent within the 2.1 second window and will discard any associated command data.

COMMUNICATING WITH THE RECEIVER

The Resolution T GPS receiver supports two message protocols: TSIP and NMEA. Communication with the receiver is through a CMOS compatible serial port. The port characteristics can be modified to accommodate your application requirements. Port parameters are stored in non-volatile memory (flash) which does not require back-up power. Table 6 lists the default port characteristics.

Software Tools

The Software Tools provided on the Starter Kit CD-ROM includes a user friendly Windows application to facilitate communication with the receiver, via the Trimble Standard Interface Protocol (TSIP).

Port Configuration

The Resolution T GPS receiver has a single I/O port. Table 6 provides the default protocol and port configuration for the receiver, as delivered from the factory. TSIP IN/OUT is the default protocol

TSIP Input	TSIP Output
Baud Rate: 9600 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control	Baud Rate: 9600 Data Bits: 8 Parity: Odd Stop Bits: 1 No Flow Control

Table 6: Default Protocol and Port Configuration

The Resolution T GPS receiver can also be configured to output NMEA messages. The industry standard port characteristics for NMEA are:

- Baud Rate: 4800
- Data Bits: 8
- Parity: None
- Stop Bits:1
- No Flow Control

Any standard serial communications program, such as Windows Hyper-Terminal or PROCOMM, can be used to view the NMEA output messages. TSIP is a binary protocol and outputs raw binary serial data that cannot be read when using Windows Terminal or PROCOMM. To view the output of the TSIP protocol in text format, use the DSP Monitor program (see the CD-ROM provided in the Starter Kit).

Warning:	When using the TSIP protocol to change port assignments or settings, confirm that your changes do not affect the ability to communicate with the receiver (e.g., selecting the PC COM port settings that do not match the receiver's, or changing the output protocol to TSIP while not using TSIPCHAT).

Port Protocol and Data Output Options

Protocol Configuration and Interface

The factory default protocol for the Resolution T GPS receiver is the Trimble Standard Interface Protocol (TSIP), for both input and output. The serial port setting is 9600 baud 8-odd-1. The receiver protocol can be re-configured using TSIP command packet 0xBC, DSP Monitor, or a user written serial interface program.

DSP Monitor (DSPMon.exe), a Windows-based GUI, provides a versatile graphical interface for monitoring TSIP data. This application allows the user to view complete receiver operations including data output, status and configuration. In this application, the entry of command packets is replaced by traditional point and click pull-down menus.

C source code example for TSIP commands are also provided in Appendix A. When used as software design templates, this source code can significantly speed-up code development.

The protocol settings and options are stored in Random-Access-Memory (RAM). They can be saved into the non-volatile memory (Flash), if desired, using command 0x8E-26.

NMEA 0183 Protocol and Data Output Options

The National Marine Electronics Association (NMEA) protocol is an industry standard data protocol which was developed for the marine industry. Trimble has chosen to adhere stringently to the NMEA 0183 data specification as published by the NMEA. The Resolution T GPS receiver also adheres to the NMEA 0183, Version 3.0 specification.

NMEA data is output in standard ASCII sentence formats. Message identifiers are used to signify what data is contained in each sentence. Data fields are separated by commas within the NMEA sentence. In the Resolution T GPS receiver, NMEA is an output only protocol.

The receiver is shipped from the factory with the TSIP protocol configured on Port 1. The receiver can be reconfigured using TSIP command packet 0xBC, in conjunction with TSIPCHAT, DSP Monitor, or a user written serial interface program.

The NMEA output messages selection and message output rate can be set using TSIP command packet 0x7A. The default setting is to output the ZDA message at a 1 second interval, when the receiver output protocol is configured to NMEA, using packet 0xBC.

If NMEA is to be permanent for the application, the protocol configuration (0xBC) and NMEA message output setting (0x7A) can be stored in the non-volatile memory (on-board flash) using TSIP command 0x8E-26.

CHAPTER

4

SYSTEM OPERATION

In this chapter:

- Operation
- PPS Output Options
- Customizing Operations

OPERATION

This chapter describes the operating characteristics of the Resolution T GPS timing receiver including start-up, satellite acquisition, operating modes, serial data communication, and the timing pulse. The Resolution T GPS timing receiver acquires satellites and computes position and time solutions. It outputs data in the TSIP (or NMEA) protocol through its serial port.

Start-Up

At power-up, the Resolution T automatically begins to acquire and track GPS satellite signals. It obtains its first fix in under one minute.

During the satellite acquisition process, the Resolution T GPS outputs periodic TSIP status messages. These status messages confirm that the receiver is working.

Automatic Operation

When the Resolution T has acquired and locked onto a set of satellites that pass the mask criteria listed below, and has obtained a valid ephemeris for each satellite, it performs a self-survey. After a number of position fixes (configurable), the self-survey is complete. At that time, the Resolution T automatically switches to a time-only mode.

Satellite Masks

The Resolution T continuously tracks and uses up to twelve satellites in an overdetermined clock solution. The satellites must pass the mask criteria to be included in the solution.

Table 4.1 lists the default satellite masks used by the Resolution T. These masks serve as the screening criteria for satellites used in fix computations and ensure that solutions meet a minimum level of accuracy. The satellite masks can be adjusted using the TSIP protocol described in Appendix A.

Mask	Setting	Notes
Elevation	10°	SV elevation above horizon
SNR (AMUs)	4	Signal strength
PDOP	12	Self-survey only

Table 7: Mask Settings

Elevation Mask

Satellites below 10° elevation are not used in the solution. Generally, signals from low-elevation satellites are of poorer quality than signals from higher elevation satellites. These signals travel farther through the ionospheric and tropospheric layers and undergo distortion due to these atmospheric conditions.

SNR Mask

Although the Resolution T is capable of tracking signals with SNRs as low as 2, the default SNR mask is set to 4 to eliminate poor quality signals from the fix computation. Low SNR values can result from low-elevation satellites, partially obscured signals (for example, dense foliage), or multi-reflected signals (multipath)

Multi-reflected signals, also known as multipath, can degrade the position and timing solution. Multipath is most commonly found in urban environments with many tall buildings and a preponderance of mirrored glass. Multi-reflected signals tend to be weak (low SNR value), since each reflection diminishes the signal. Setting the SNR mask to 4 or higher minimizes the impact of multi-reflected signals.

PDOP Mask

Position Dilution of Position (PDOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets that are tightly clustered or aligned in the sky have a high PDOP and contribute to lower position accuracy. For timing applications, a PDOP mask of 12 offers a satisfactory trade-off between accuracy and GPS coverage. With worldwide GPS coverage, the PDOP mask can be lowered even more for many applications without sacrificing coverage.

NOTE: PDOP is only applicable during self-survey or whenever the receiver is performing position fixes.

Tracking Modes

The Resolution T operates in one of two main fix modes:

- Self-Survey (Position fix mode)
- Overdetermined Clock mode

After establishing a reference position in Self-Survey mode, the Resolution T automatically switches to Overdetermined (OD) Clock mode.

Self-Survey Mode

At power-on, the Resolution T performs a self-survey by averaging 600 position fixes. The number of position fixes until survey completion is configurable using the 8E-A9 command.

The default mode during self-survey is 3-D manual, where the receiver must obtain a 3-D solution with a PDOP below the PDOP mask. The PDOP mask criteria can be set and queried using a TSIP packet. If fewer than four conforming satellites are visible, the Resolution T suspends the self survey.

The highest accuracy fix mode is 3-D manual, where altitude is always calculated along with the latitude, longitude, and time. Obtaining a position requires four satellites with a PDOP below the PDOP mask. Depending on how the PDOP mask is set, 3-D mode can be restrictive when the receiver is subjected to frequent obscuration or when the geometry is poor due to an incomplete constellation.

Overdetermined Clock Mode

Overdetermined Clock Mode is used only in stationary timing applications. This is the default mode for the Resolution T once a surveyed (or user input) position is determined. After the receiver self-surveys its static reference position, it automatically switches to Overdetermined Clock Mode and determines the clock solution. The timing solution is qualified by a TRAIM algorithm, which automatically detects and rejects faulty satellites from the solution.

In this mode, the Resolution T does not navigate or update positions and velocities, but maintains the PPS output, solving only for the receiver clock error (bias) and error rate (bias rate).

PPS QUANTIZATION ERROR

The Resolution T uses a high-precision, fixed frequency oscillator as the timing source to down-convert and decode the GPS signal and to generate the PPS output signal. Since a fixed-frequency oscillator is used, the Resolution T must place the PPS output on the clock edge that it determines is closest to UTC or GPS. This situation results in a quantization error on the placement of the PPS whose magnitude is equal to one-half the period of the fixed frequency oscillator. The oscillator frequency is 12.504 MHz which is equivalent to a period just under 80 nanoseconds. Since both clock edges are used, the quantization error on the PPS output is between ±20ns.

The quantization error is illustrated below. The top waveform represents the 12.504 MHz clock. The Resolution T output must be placed on one of the edges of this clock. The middle waveform represents the UTC/GPS on-time mark as determined by the receiver's electronics. The bottom waveform represents the Resolution T PPS output which is output on the clock edge closest to the actual UTC/GPS on-time mark.

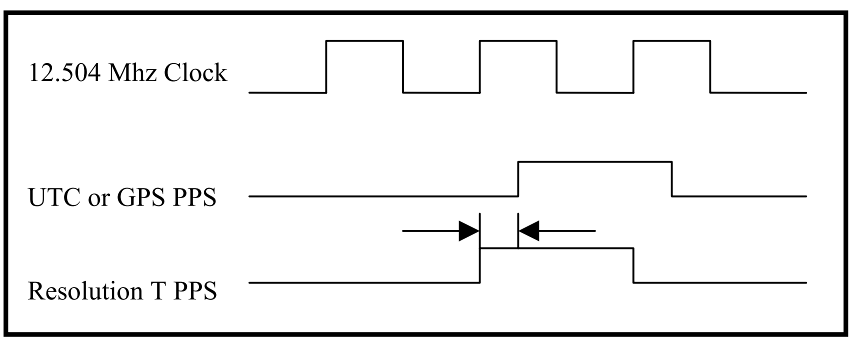
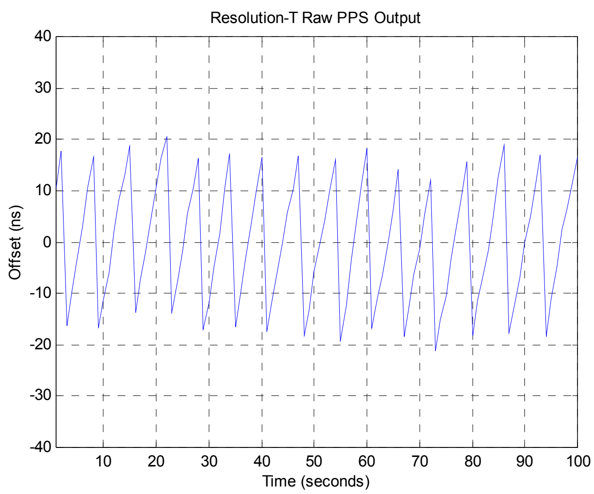
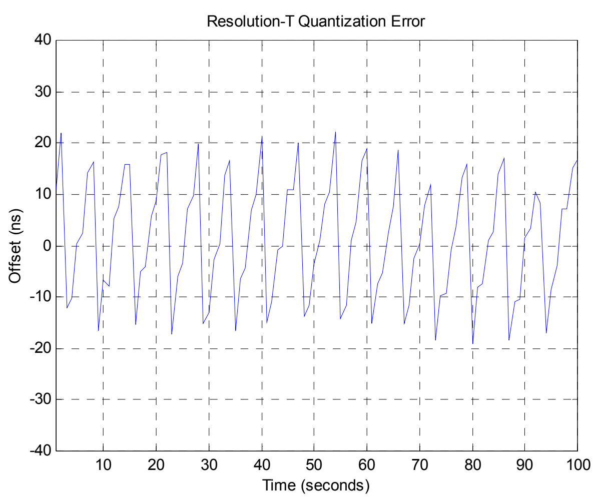


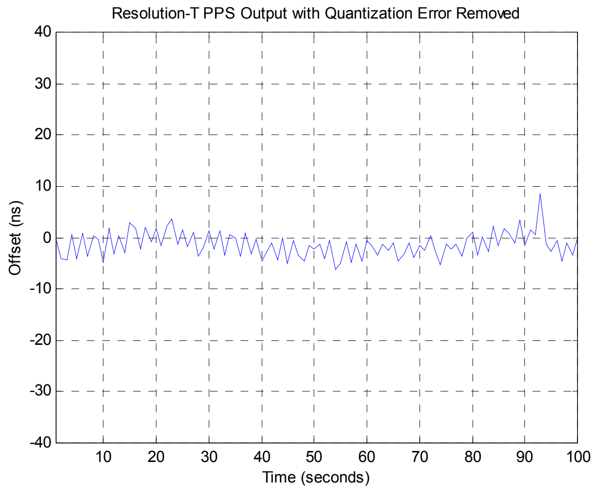
Figure 9—PPS Quantization Error

The amount of quantization error present on each PPS output pulse is reported in packet 0x8F-AC. This quantization error information can be used to reduce the effective amount of jitter on the PPS pulse.

The figures below illustrate the result of removing the quantization error from the PPS output in a user system. The top slot shows the offset of the PPS output pulse relative to a stable standard such as a Cesium atomic clock. The quantization error is responsible for the jagged appearance of the waveform. The middle plot shows the quantization error as reported by the Resolution T in packet 0x8F-AC. The bottom plot is the result of subtracting the quantization error from the PPS offset.






Resolution-T PPS Output with Quantization Error Removed
Offset (ns)
Time (seconds)
40
30
20
10
0
-10
-20
-30
-40
10
20
30
40
50
60
70
80
90
100

SERIAL DATA COMMUNICATION

The Resolution T outputs TSIP super packets or NMEA messages, Immediately following power-on, the Resolution T outputs packets 8F-AB, 8F-AC, and PPS. Use packet 8E-A5 to enable or disable timing packets and automatic output packets. These packets are described in Appendix A.

The factory default port setting is 9600 baud in/out, 8 data bits, odd parity, 1 stop bit. The serial port setting can be changed and stored in FLASH MEMORY using a TSIP command. This port can be configured to transmit timing packets, using packet 8E-A5.

GPS Timing

For many timing applications, such as time/frequency standards, site synchronization systems, and wireless voice and data networks, the Resolution T can be used to steer a local reference oscillator. The steering algorithm combines the short-term stability of the oscillator with the long-term stability of the GPS PPS. An accurate GPS PPS allows the use of cost-effective crystal oscillators, which have less stability than expensive, high-quality oscillators, such as OCXO's (Oven Controlled Crystal Oscillator).

The GPS constellation consists of at least 24 orbiting satellites. Unlike most telecommunications satellites, GPS satellites are not geostationary, so satellites in view are constantly changing. Each GPS satellite contains four highly-stable atomic clocks, which are continuously monitored and corrected by the GPS control segment. Consequently, the GPS constellation can be considered a set of 24 orbiting "clocks" with worldwide 24-hour coverage.

A Trimble GPS receiver uses the signals from these GPS “clocks” to correct its internal clock, which is not as stable or accurate as the GPS atomic clocks. A GPS receiver like the Resolution T outputs a highly accurate timing pulse (PPS) generated by its internal clock, which is constantly corrected using the GPS clocks. In the case of the Resolution T, this timing pulse is synchronized to GPS/UTC time within 15 nanoseconds (1σ) after survey is complete.

In addition to serving as highly-accurate stand-alone time sources, GPS timing receivers are used to synchronize distant clocks in communication or data networks. This is possible because all GPS satellites are corrected to a common master clock. Therefore, the relative clock error is the same, regardless of which satellites are used. For synchronization applications requiring a common clock, GPS is the ideal solution.

Position and time errors are related by the speed of light. This is why an accurate reference position is critical. A position error of 100 meters corresponds to a time error of approximately 333 ns.

The GPS receiver's clocking rate and software affect PPS accuracy. The Resolution T has a clocking rate of 12.504 MHz which enables a steering resolution of 40 ns (±20 ns). Utilizing both the rising edge and falling edge of the pulse will enable a steering resolution of ±20ns. Using software algorithms like an overdetermined clock solution, the Resolution T mitigates the effects of clock error to achieve a PPS accuracy within 15 ns (1σ) to GPS/UTC after survey is complete.

Timing Operation

The Resolution T automatically outputs a PPS and time tag. With an accurate reference position, the receiver automatically switches to an overdetermined clock mode, activates its TRAIM algorithm and outputs a precise PPS. Using a simple voting scheme based on pseudo-range residuals, the Resolution T integrity algorithm automatically removes the worst satellite with the highest residual from the solution set if that satellite's residual is above a certain threshold.

The Resolution T's default configuration provides optimal timing accuracy. The only item under user or host control that can affect the receiver's absolute PPS accuracy is the delay introduced by the antenna cable. For long cable runs, this delay can be significant (1.25 ns per foot). TSIP packet 8Ex4A sets the cable delay parameter, which is stored in non-volatile memory. For the best absolute PPS accuracy, adjust the cable delay to match the installed cable length (check with your cable manufacturer for the delay for a specific cable type). Generally, the cable delay is about 1.25 nanoseconds per foot of cable. To compensate for the cable delay, use a negative offset to advance the PPS output.

NOTE: GPS time differs from UTC (Universal Coordinated Time) by a small, sub-microsecond offset and an integer-second offset. The small offset is the steering offset between the GPS DoD clock ensemble and the UTC (NIST) clock ensemble. The large offset is the cumulative number of leap seconds since 1 January 1970, which, on 31 December 1998, was increased from 12 to 13 seconds. Historically, the offset increases by one second approximately every 18 months, usually just before midnight on 30 June or 31 December. **System designers should note whether the output time is UTC or GPS time**.

USING RESOLUTION T IN MOBILE APPLICATIONS

Although it is intended primarily for use in static applications, the Resolution T can also be used in mobile applications. The factory default settings for the Resolution T assume that the antenna is going to be used in a static timing application. To use the Resolution T in mobile applications, you must disable the receiver's self-survey mechanism and ensure that a stored position does not exist in the flash ROM.

To prepare the Resolution T receiver for mobile applications, complete the following steps.

- Confirm that there is no stored position in the flash ROM by using command packet 8E-A6 to delete the stored position (if one exists).
- Disable the self-survey mechanism using command packet 8E-A9. If not disabled, the self-survey mechanism will automatically survey the antenna's position and then set the receiver to operate in a static, time-only mode.
- Set the desired position fix mode using command packet BB.
- Optionally, use packet 8E-A5 to enable the automatic output packets such as position and velocity.
- Use packet 8E-26 to save this new configuration to Flash storage and to retain these settings during power cycles and resets.

After these steps are completed, the Resolution T receiver is ready to operate properly in mobile applications. While operating in a mobile application, the receiver can continue to output a PPS pulse as well as timing packets.

NOTE: The accuracy of the PPS output pulse will be degraded by a factor of about 3 when the unit is operated in a mobile application.

CUSTOMIZING OPERATIONS

The Resolution T receiver provides a number of user configurable parameters that allow you to customize the operation of the unit. These parameters are stored in flash ROM chip to be retained during loss of power and through resets. At reset or power-up, the receiver configures itself based on the parameters stored in the flash ROM. You can change the values of these parameters to achieve the desired operations using a variety of TSIP packets. The Resolution T configures itself based on the new parameter immediately, but the new parameter value is not automatically saved to the flash ROM. You must direct the receiver to save the parameters to the flash ROM.

To change the parameter values stored in flash ROM, send packet 0x8E-26 to direct the Resolution T to save the current parameter values to the flash ROM. To save or delete the stored position, use command packet 0x8E-A6. You can also direct the receiver to set the parameter values to their factory default settings (and to erase the stored position) with packet 0x1E.

In brief, to customize the Resolution T GPS receiver operations for your application:

- Configure the receiver using TSIP command packets until the desired operation is achieved.
- Use TSIP packet 0x8E-26 to save the settings in non-volatile memory (flash ROM.)
- If the position was not automatically saved during the self survey or if it was manually entered, the position can be saved to Flash using TSIP packet 8E-A6.

The new settings will control receiver operations whenever it is reset or power cycled.

Configuration Parameters

The following tables list the user configurable parameters. Each table lists the parameter name, its factory default value, and the TSIP packet that sets or reads the parameter value (typically, one TSIP packet sets or reads several related parameters.)

SYSTEM ARCHITECTURE

The Resolution T is a software GPS timing receiver. It is a complete all-in-view, 12 channel, parallel tracking GPS receiver designed to operate with the L1 frequency, standard position service, Coarse Acquisition code. Included are a saw filter, Colossus RF ASIC, a 12.504 TCXO, Texas Instruments 5509 DSP, real time clock (RTC is inside the 5509 DSP), 4Mbits external RAM, and 16Mbits Flash ROM.

The Resolution T receives the amplified GPS satellite signals through the antenna feed line connector and passes them to the RF down converter. A highly stable crystal reference oscillator operating at 12.504 MHz is used by the down converter to produce the signals used by the General Purpose DSP. The General Purpose DSP tracks the GPS satellite signals and extracts the carrier code information as well as the navigation data at 50 bits per second.

Operation of the tracking channels is controlled by the navigation processor. The software tracking channels are used to track the highest twelve satellites above the horizon. The navigation processor will then use the optimum satellite combination to compute a position. The navigation processor also manages the ephemeris and almanac data for all of the satellites, and performs the data I/O.

APPENDIX

A

NMEA 0183

This appendix provides a brief overview of the NMEA 0183 protocol, and describes both the standard and optional messages offered by the Resolution T.

INTRODUCTION

NMEA 0183 is a simple, yet comprehensive ASCII protocol which defines both the communication interface and the data format. The NMEA 0183 protocol was originally established to allow marine navigation equipment to share information. Since it is a well established industry standard, NMEA 0183 has also gained popularity for use in applications other than marine electronics. The latest release of NMEA 0183 is Version 3.0 (July 1, 2000). Trimble Navigation supports both version 2.1 and version 3.0. The primary change in release 3.0 is the addition of the mode indicators in the GLL, RMC, and VTG messages.

For those applications requiring output only from the GPS receiver, NMEA 0183 is a popular choice since, in many cases, an NMEA 0183 software application code already exists. The Resolution T is available with firmware that supports a subset of the NMEA 0183 messages: GGA, GLL, GSA, GSV, RMC, VTC, and ZDA. For a nominal fee, Trimble can offer custom firmware with a different selection of messages to meet your application requirements.

For a complete copy of the NMEA 0183 standard, contact:

NMEA National Office
PO Box 3435
New Bern, NC 28564-3435
U.S.A.
Telephone: +1-919-638-2626
Fax: +1-919-638-4885

THE NMEA 0183 COMMUNICATION INTERFACE

NMEA 0183 allows a single source (talker) to transmit serial data over a single twisted wire pair to one or more receivers (listeners). The table below lists the standard characteristics of the NMEA 0183 data transmissions.

Signal	NMEA Standard
Baud Rate	4800
Data Bits	8
Parity	None (Disabled)
Stop Bits	1

Table 8: NMEA 0183 Characteristics

NMEA 0183 MESSAGE FORMAT

The NMEA 0183 protocol covers a broad array of navigation data. This broad array of information is separated into discrete messages which convey a specific set of information. The entire protocol encompasses over 50 messages, but only a sub-set of these messages apply to a GPS receiver like the Resolution T. The NMEA message structure is described below.

```
$IDMSG,D1,D2,D3,D4,.......,Dn*CS[CR][LF]
```

"$" The "$" signifies the start of a message.

ID The talker identification is a two letter mnemonic which describes the source of the navigation information. The GP identification signifies a GPS source.

MSG The message identification is a three letter mnemonic which describes the message content and the number and order of the data fields.

"," Commas serve as delimiters for the data fields.

Dn Each message contains multiple data fields (Dn) which are delimited by commas.

"*" The asterisk serves as a checksum delimiter.

CS The checksum field contains two ASCII characters which indicate the hexadecimal value of the checksum.

[CR][LF] The carriage return [CR] and line feed [LF] combination terminate the message.

NMEA 0183 messages vary in length, but each message is limited to 79 characters or less. This length limitation excludes the "$" and the [CR][LF]. The data field block, including delimiters, is limited to 74 characters or less.

FIELD DEFINITIONS

Many of the NMEA date fields are of variable length, and the user should always use the comma delineators to parse the NMEA message date field. Table\ specifies the definitions of all field types in the NMEA messages supported by Trimble

Type	Symbol	Definition
Status	A	Single character field: A=Yes, data valid, warning flag clear V=No, data invalid, warning flag set
Special Format Fields		
Latitude	llll.lll	Fixed/variable length field: Degreesminutes.decimal-2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Longitude	yyyyy.yyy	Fixed/Variable length field: Degreesminutes.decimal-3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.

Time	hhmmss.ss	Fixed/Variable length field: hoursminutesseconds.decimal-2 fixed digits of minutes, 2 fixed digits of seconds and a variable number of digits for decimal-fraction of seconds. Leading zeros always included for hours, minutes, and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Defined		Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in this standard by the presence of one or more valid characters. Excluded from the list of allowable characters are the following that are used to indicated field types within this standard: “A”, “a”, “c”, “hh”, “hhmmss.ss”, “llll.ll”, “x”, “yyyyy.yy”
Numeric Value Fields		
Variable	x.x	Variable length integer or floating numeric field. Optional leading and trailing zeros. The decimal point and associated decimal-fraction are optional if full resolution is not required (example: 73.10=73.1=073.1=73).
Fixed HEX	hh	Fixed length HEX numbers only, MSB on the left
Information Fields		
Fixed Alpha	aa	Fixed length field of upper-case or lower-case alpha characters.
Fixed Number	xx	Fixed length field of numeric characters

Table 9: Field Type Summary

NOTES Spaces are only be used in variable text fields.

Units of measure fields are appropriate characters from the Symbol column unless a specified unit of measure is indicated.

Fixed length field definitions show the actual number of characters. For example, a field defined to have a fixed length of 5 HEX characters is represented as hhhhh between delimiters in a sentence definition.

NMEA 0183 MESSAGE OPTIONS

The Resolution T can output any or all of the messages listed in the table below. In its default configuration (as shipped from the factory), the Resolution T outputs only TSIP messages. Typically NMEA messages are output at a 1 second interval with the "GP" talker ID and checksums. These messages are output at all times during operation, with or without a fix. If a different set of messages has been selected (using Packet 0x7A), and this setting has been stored in Flash memory (using Packet 0x8E-26), the default messages are permanently replaced until the receiver is returned to the factory default settings.

Note: The user can configure a custom mix of the messages listed in the table below. See Chapter 3, and TSIP command packets 0xBC, 0x7A, and 8E-26 in Appendix A for details on configuring NMEA output.

Warning: If too many messages are specified for output, you may need to increase the unit's baud rate.

	Message	Description
	GGA	GPS fix data
	GLL	Geographic position - Latitude/Longitude
	GSA	GPS DOP and active satellites
	GSV	GPS satellites in view
	RMC	Recommended minimum specific GPS/Transit data
	VTG	Track made good and ground speed
	ZDA	Time and date

Table 10: NMEA Messages

NMEA 0183 MESSAGE FORMATS

GGA-GPS Fix Data

The GGA message includes time, position and fix related data for the GPS receiver.

```
$GPGGA,hhmmss.ss,llll.lll,a,nnnnn.nnn,b,t,uu,
v.v,w.w,M,x.x,M,y.y,zzzz*hh <CR><LF>
```

Field #	Description
1	UTC of Position
2, 3	Latitude, N (North) or S (South)
4, 5	Longitude, E (East) or W (West)
6	GPS Quality Indicator: 0 = No GPS, 1 = GPS, 2 = DGPS
7	Number of Satellites in Use
8	Horizontal Dilution of Precision (HDOP)
9, 10	Antenna Altitude in Meters, M = Meters
11, 12	Geoidal Separation in Meters, M=Meters. Geoidal separation is the difference between the WGS-84 earth ellipsoid and mean-sea-level.
13	Age of Differential GPS Data. Time in seconds since the last Type 1 or 9 Update
14	Differential Reference Station ID (0000 to 1023)
hh	Checksum

Table 11: GGA Message

GLL - Geographic Position - Latitude/Longitude

The GLL message contains the latitude and longitude of the present vessel position, the time of the position fix and the status.

```
$GPGLL,llll.lll,a,yyyyy.yyy,a,hhmmss.ss,A,i*hh
<CR> <LF>
```

Field #	Description
1	Latitude, N (North) or S (South)
2, 3	Longitude, E (East) or W (West)
5	UTC of position
6	Status: A = Valid, V= Invalid
7	Mode Indicator A=Autonomous Mode D=Differential Mode E=Estimated (dead reckoning) Mode M=Manual Input Mode S=Simulated Mode N-Data Not Valid
hh	Checksum

Table 12: GLL Message

GSA - GPS DOP and Active Satellites

The GSA messages indicates the GPS receiver's operating mode and lists the satellites used for navigation and the DOP values of the position solution.

```
$GPGSA,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,
xx,x.x,x.x,x.x*hh<CR><LF>
```

Field #	Description
1	Mode: M = Manual, A = Automatic. In manual mode, the receiver is forced to operate in either 2D or 3D mode. In automatic mode, the receiver is allowed to switch between 2D and 3D modes subject to the PDOP and satellite masks.
2	Current Mode: 1 = fix not available, 2 = 2D, 3 = 3D
3 - 14	PRN numbers of the satellites used in the position solution. When less than 12 satellites are used, the unused fields are null
15	Position dilution of precision (PDOP)
16	Horizontal dilution of precision (HDOP)
17	Vertical dilution of precision (VDOP)
hh	Checksum

Table 13: GSA Message

GSV - GPS Satellites in View

The GSV message identifies the GPS satellites in view, including their PRN number, elevation, azimuth and SNR value. Each message contains data for four satellites. Second and third messages are sent when more than 4 satellites are in view. Fields #1 and #2 indicate the total number of messages being sent and the number of each message respectively.

```
$GPGSV,x,x,xx,xx,xx,xxx,xx,xx,xx,xxx,xx,xx,xx,

xxx,xx,xx,xx,xxx,xx*hh<CR><LF>
```

Field #	Description
1	Total number of GSV messages
2	Message number: 1 to 3
3	Total number of satellites in view
4	Satellite PRN number
5	Satellite elevation in degrees (90° Maximum)
6	Satellite azimuth in degrees true (000 to 359)
7	Satellite SNR (C/No), null when not tracking
8, 9, 10, 11	PRN, elevation, azimuth and SNR for second satellite
12, 13, 14, 15	PRN, elevation, azimuth and SNR for third satellite
16, 17, 18, 19	PRN, elevation, azimuth and SNR for fourth satellite
hh	Checksum

Table 14: GSV Message

RMC - Recommended Minimum Specific GPS/Transit Data

The RMC message contains the time, date, position, course, and speed data provided by the GPS navigation receiver. A checksum is mandatory for this message and the transmission interval may not exceed 2 seconds. All data fields must be provided unless the data is temporarily unavailable. Null fields may be used when data is temporarily unavailable.

```
$GPRMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,x.x,x.
x,xxxxxx,x.x,a,i*hh<CR><LF>
```

Field #	Description
1	UTC of Position Fix.
2	Status: A = Valid, V = navigation receiver warning
3, 4	Latitude, N (North) or S (South).
5, 6	Longitude, E (East) or W (West).
7	Speed over the ground (SOG) in knots
	Track made good in degrees true.
	Date: dd/mm/yy
	Magnetic variation in degrees, E = East / W= West
	Position System Mode Indicator; A=Autonomous, D=Differential, E=Estimated (Dead Reckoning), M=Manual Input, S=Simulation Mode, N=Data Not Valid
hh	Checksum (Mandatory for RMC)

Table 15: RMC Message

VTG - Track Made Good and Ground Speed

The VTG message conveys the actual track made good (COG) and the speed relative to the ground (SOG).

$GPVTG,x.x,T,x.x,M,x.x,N,x.x,K,i*hh<CR><LF>

Field #	Description
1	Track made good in degrees true.
2	Track made good in degrees magnetic.
3, 4	Speed over the ground (SOG) in knots.
5, 6	Speed over the ground (SOG) in kilometer per hour.
7	Mode Indicator: A=Autonomous Mode, D=Differential Mode, E=Estimated (dead reckoning) Mode, M=Manual Input Mode, S=Simulated Mode, N-Data Not Valid
hh	Checksum

Table 16: VTG Message

ZDA - Time & Date

The ZDA message contains UTC time, the day, the month, the year and the local time zone.

`$GPZDA,hhmmss.ss,xx,xx,xxxx,,*hh<CR><LF>`

Field #	Description
1	UTC
2	Day (01 to 31)
3	Month (01 to 12)
4	Year
5	Unused
6	Unused
hh	Checksum

Table 17: ZDA Message

NOTE: Fields #5 and #6 are null fields in the Resolution T output. A GPS receiver cannot independently identify the local time zone offsets.

WARNING: If UTC offset is not available, time output will be in GPS time until the UTC offset value is collected from the GPS satellites. When the offset becomes available, the time will jump to UTC time.

NOTE: GPS time can be used as a timetag for the 1PPS. The ZDA message comes out 100-500 msec after the PPS.

EXCEPTION BEHAVIOR

When no position fix is available, some of the data fields in the NMEA messages will be blank. A blank field has no characters between the commas.

Interruption of GPS Signal

If the GPS signal is interrupted temporarily, the NMEA will continue to be output according to the user-specified message list and output rate. Position and velocity fields will be blank until the next fix, but most other fields will be filled.

APPENDIX

B

TRIMBLE STANDARD INTERFACE PROTOCOL (TSIP)

The Trimble Standard Interface Protocol (TSIP) may be characterized as a set of data packets used to transmit information to and receive information from a Trimble GPS receiver. Trimble products commonly support a version of TSIP which is customized to the attributes of the product. This appendix describes the Resolution T customization.

INTRODUCTION

TSIP is a powerful and compact interface protocol which has been designed to allow the system developer a great deal of flexibility in interfacing to a Trimble product. Many TSIP data packets are common to all products which use TSIP. An example would be a single precision position output packet. Other packets may be unique to a product. Custom packets are only used in the products for which they have been created.

NOTE: This appendix has been generated and reviewed with care, however, history has shown that it is surprisingly difficult to generate a TSIP appendix which is entirely free of errors. There is no reason to believe that this appendix will be an exception. Trimble is always grateful to receive reports of any errors in either products or documentation.

Interface Scope

The Resolution T GPS module has one configurable serial I/O communication port, which is a bi-directional control and data port utilizing a Trimble Standard Interface Protocol (TSIP). The data I/O port characteristics and other options are user programmable and stored in non-volatile memory (Flash EPROM.)

The TSIP protocol is based on the transmission of packets of information between the user equipment and the GPS receiver. Each packet includes an identification code that identifies the meaning and format of the data that follows. Each packet begins and ends with control characters.

Automatic Output Packets

The Resolution T GPS embedded timing board is configured to automatically output the 0x8F-AB and 0x8F-AC packets. For most system implementations these output packets provide all of the information required for operation including time, position, GPS status, and health. The following packets can be broadcast if enabled with packet 0x8E-A5 and 0x35. By default, only packets 0x8F-AB and 0x8F-AC are enabled for output.

Broadcast Packet ID	Description	Masking Packet ID	Request Packet ID	When Sent
0x42	Position XYZ (ECEF), single precision	0x35	0x37	When a position fix is computed
0x43	Velocity XYZ, single precision	0x35	0x37	When a position fix is computed
0x4A	Position LLA, single precision	0x35	0x37	When a position fix is computed
0x56	Velocity ENU, single precision	0x35	0x37	When a position fix is computed
0x58	Satellite system data	none	0x38	When new system data is received
0x6D	Satellite list, DOPS, mode	none	0x24	When the satellite selection list is updated
0x83	Position XYZ (ECEF),double precision	0x35	0x37	When a position fix is computed
0x84	Position LLA, double precision	0x35	0x37	When a position fix is computed
0x8F-AB	Primary timing packet	0x8E-A5	none	Once per second
0x8F-AC	Secondary timing packet	0x8E-A5	none	Once per second

Table 18: Broadcast Output Packets

Customizing Operations Parameters

The Resolution T provides a number of user configurable parameters that allow the user to customize the operation of the Resolution T. These parameters are stored in flash memory to be retained during loss of power and through resets. At reset or power up, the Resolution T configures itself based on the parameters stored in the flash. The user can change the values of these parameters to achieve the desired operation using a variety of TSIP packets. The Resolution T configures itself based upon the new parameters immediately, but the new parameter is not automatically saved to flash. The user must direct the Resolution T to save the parameters to flash. To change the parameter values stored in flash, the user sends packet 0x8E-26 to direct the Resolution T to save the current parameters in the flash. Users can also direct the Resolution T to set the parameter values to their factory default with packet 0x1E.

NOTE: Whenever configuration data is saved to the Flash EPROM (using 0x8E-26 or other packets) the Resolution T will automatically perform a reset.

To customize the Resolution T output for your application:

- Set up the Resolution T using TSIP commands until the desired operation is achieved.
- Use command 0x8E-26 to store the settings in non-volatile memory.

These settings will control Resolution T operations whenever it is cold-started. The following tables illustrate how the user configurable data is mapped. The Trimble factory defaults are also provided. See packet 0x1E.

Parameter	Factory Default	Set	Request	Report
Receiver mode	4 (Full Position 3D)	0xBB	0xBB	0xBB
Dynamics code	1 (land)			
elevation mask	0.175 radians (10 deg)			
signal level mask	4(AMU)			
PDOP mask	12			
PDOP switch	6			
foliage mode	1sometimes			

Table 19: Factory Default Settings

Parameter	Factory Default	Set	Request	Report
Packet broadcast mask mask 0 mask 1	 0x05 0x00	0x8E-A5	0x8E-A5	0x8F-A5
Packet 0x35 data position (byte 0) velocity (byte 1) timing (byte 2) auxiliary (byte 3)	 0x12 0x02 0x00 0x00	0x35	0x35	0x35
Datum	0 WGS-84	0x8E-15	0x8E-15	0x8F-15

Table 20: Packet I/O Control

Parameter	Factory Default	Set	Request	Report
Input baud rate	7 (9600 baud)	0xBC	0xBC	0xBC
Output baud rate	7 (9600 baud)			
Data bits	8			
Parity	1 (odd)			
Stop bits	1			
Input protocol	2 (TSIP)			
Output protocol	2 (TSIP)			

Table 21: Serial Port Configuration

Parameter	Factory Default	Set	Request	Report
PPS enable	1 (enabled)	0x8E-4A	0x8E-4A	0X8F-4A
PPS sense	1 (rising edge)			
PPS offset	0.0 (seconds)			
Bias Uncertainty Threshold	300.0(Meters)	0x8E-4A	0x8E-4A	0x8F-4A
PPS Output Qualifier	2 (always on)	0x8E-4E	0x8E-4E	0x8F-4E
UTC/GPS Date/Time	0 (GPS)	0x8E-A2	0x8E-A2	0x8F-A2
UTC/GPS PPS Alignment	0 (GPS)	0x8E-A2	0x8E-A2	0x8F-A2

Table 22: Timing Outputs

Parameter	Factory Default	Set	Request	Report
Position	No stored position	0x31, 0x32, self-survey	0x8E-AC	0x8F-AC

Table 23: Accurate Position

Self-Survey	Factory Default	Set	Request	Report
Self-survey enable	1 (enabled)	0x8E-A9	0x8E-A9	0x8F-A9
Position save flag	1 (save)			
Self-survey count	600 (fixes)			

Table 24: Self-Survey

Packets Output at Power-Up

After completing its self-diagnostics, the Resolution T automatically outputs the following packets.

Output ID	Description	Notes
0x45	Software version	

Table 25: Packet Power-up Output Messages

Report Packets: Resolution T to User

The table below summarizes the packets output by the Resolution T. The table includes the output packet ID, a short description of each packet, and the associated input packet. In some cases, the response packets depend on user-selected options.

Output ID	Packet Description	Input ID
0x42	single-precision XYZ position	0x37, auto
0x43	velocity fix (XYZ ECEF)	0x37, auto
0x45	software version information	0x1E, 0x1F, power-up
0x47	signal level for all satellites	0x27
0x4A	single-precision LLA position	0x37, auto
0x55	I/O options	0x35
0x56	velocity fix (ENU)	0x37, auto
0x57	information about last computed fix	0x37
0x58	GPS system data/acknowledge	0x38
0x59	sat enable/disable & health flag	0x39
0x5A	raw measurement data	0x3A
0x5C	satellite tracking status	0x3C
0x6D	all-in-view satellite selection	0x24, auto
0x83	double-precision XYZ	0x37, auto
0x84	double-precision LLA	0x37, auto
0xBB	primary configuration	0xBB
0xBC	port configuration	0xBC
0x8F-15	current datum values	0x8E-15
0x8F-41	stored manufacturing operating parameters	0x8E-41
0x8F-42	stored production parameters	0x8E-42

Output ID	Packet Description	Input ID
0x8F-4A	set PPS characteristics	0x8E-4A
0x8F-A2	UTC/GPS timing	0x8E-A2
0x8F-A4	test modes	0x8E-A4
0x8F-4E	PPS output option	0x8E-4E
0x8F-A5	packet broadcast mask	0x8E-A5
0x8F-A6	Self survey command	0x8E-A6
0x8F-A9	Self survey parameters	0x8E-A9
0x8F-AB	primary timing packet	auto
0x8F-AC	supplemental timing packet	auto

Table 26: Report Packets

Command Packets: User to Resolution T

The table below summarizes the packets that can be input by the user. The table includes the input packet ID, a short description of each packet, and the associated output packet.

Input ID	Packet Description	Output ID
0x1E	Initiate cold reset or factory reset	0x45
0x1F	software version	0x45
0x24	request GPS satellite selection	0x6D
0x25	initiate soft reset & self-test	0x45
0x27	request signal levels	0x47
0x31	set accurate initial position (XYZ ECEF)	--
0x32	set accurate initial position (lat, long, Alt)	--
0x34	satellite selection for one-satellite mode	--
0x35	set/request I/O options	0x55
0x37	status and values of last position and velocity	0x57 (and other enabled packets)
0x38	load or request satellite system data	0x58
0x39	set/request satellite disable or ignore health	0x59
0x3A	request last raw measurement	0x5A
0x3C	request current satellite tracking status	0x5C
0x7A	NMEA Set/Request	
0x7B	NMEA Output Interval	
0xBB	set receiver configuration	0xBB
0xBC	set port configuration	0xBB
0x8E-4E	PPS output option	0x8F-4E
0x8E-15	set/request current datum	0x8F-15
0x8E-26	Save configuration	
0x8E-41	request manufacturing parameters	0x8F-41
0x8E-42	request production parameters	0x8F-42
0x8E-4A	set PPS characteristics	0x8F-4A
0x8E-A2	UTC/GPS timing	0x8F-A2
0x8E-A4	test modes	0x8F-A4
0x8E-A5	packet broadcast mask	0x8F-A5
0x8E-A6	self-survey commands	0x8F-A6
0x8E-A9	self-survey parameters	0x8F-A9

Table 27: Command Packets

Packet Structure

TSIP packet structure is the same for both commands and reports. The packet format is:

```
<DLE> <id> <data string bytes> <DLE> <ETX>
```

Where:

<DLE> is the byte 0x10

<ETX> is the byte 0x03

<id> is a packet identifier byte, which can have any value excepting <ETX> and <DLE>.

The bytes in the data string can have any value. To prevent confusion with the frame sequences <DLE> <id> and <DLE> <ETX>, every <DLE> byte in the data string is preceded by an extra <DLE> byte (‘stuffing’). These extra <DLE> bytes must be added (‘stuffed’) before sending a packet and removed after receiving the packet. Notice that a simple <DLE> <ETX> sequence does not necessarily signify the end of the packet, as these can be bytes in the middle of a data string. The end of a packet is <ETX> preceded by an odd number of <DLE> bytes.

Multiple-byte numbers (integer, float, and double) follow the ANSI / IEEE Std. 754 IEEE Standard for binary Floating-Point Arithmetic. They are sent most-significant byte first. ***Note that switching the byte order will be required in Intel-based machines***. The data types used in the Resolution T TSIP are defined below.

- UINT8 - An 8 bit unsigned number (0 to 255).
- SINT8 - An 8 bit signed number (-128 to 127).
- INT16 - A 16 bit unsigned number (0 to 65,535).
- SINT16 - A 16 bit signed number (-32,768 to 32,767).
- UINT32 - A 32 bit unsigned number (0 to 4,294,967,295)
- SINT32 - A 32 bit signed number (-2,147,483,648 to 2,147,483,647).
  - Single — Float (4 bytes) (3.4x10-38 to 1.7x1038) (24 bit precision)
  - Double — Float (8 bytes) (1.7x10-308 to 3.4x10308) (53 bit precision)

Note: Default serial port settings are 9600-8-odd-1.

Packet Descriptions

Command Packet 0x1E: Clear RAM then Reset

This packet commands the Resolution T to perform either a cold reset, warm reset or a factory reset. A cold reset will clear the GPS data (almanac, ephemeris, etc.) stored in RAM and is equivalent to a power cycle. A factory reset will additionally restore the factory defaults of all configuration parameters stored in flash memory. A warm reset clears ephemeris and oscillator uncertainty but retains the last position, time and almanac. This packet contains one data byte. The data format is shown below.

Byte	Item	Type	Value	Meaning
0	Reset	UINT8	0x4B	Cold reset
			0x0E	Warm reset
			0x46	Factory reset

Table 28: Command Packet 0x1E Data Format

NOTE: The factory reset command will delete the stored position and cause self survey to restart.

Command Packet 0x1F: Request Software Version

This packet requests information about the version of software in the Resolution T. This packet contains no data. The GPS receiver returns packet 0x45.

Command Packet 0x24: Request GPS Satellite Selection

This packet requests a list of satellites used for the current position/time fix. This packet contains no data. The GPS receiver returns packet 0x6D.

Command Packet 0x25: Initiate Hot Reset & Self Test

This packet commands the GPS receiver to perform a software (hot) reset. This is **not** equivalent to cycling the power; RAM is not cleared. The GPS receiver performs a self-test as part of the reset operation. This packet contains no data. Following completion of the reset, the receiver will output the start-up messages. The GPS receiver sends packet 0x45 on power-up reset, and on request; thus, if packet 0x45 appears unrequested, then either the GPS receiver power was cycled or the GPS receiver was reset.

Command Packet 0x27: Request Signal Levels

This packet requests signal levels for all satellites currently being tracked. This packet contain no data. The GPS receiver returns packet 0x47 hex.

Command Packet 0x31: Accurate Initial Position (XYZ Cartesian ECEF)

This packet provides an accurate initial position to the GPS receiver in XYZ coordinates. Either the single precision or the double precision version of this packet may be used, however, we recommend using the double precision version for greatest accuracy. The GPS receiver uses this position for performing time-only fixes. If a survey is in progress when this command is sent, the survey is aborted, and this position data is used immediately. The Resulution T will automatically switch to the overdetermined timing mode. Note that this position is not automatically saved to Flash memory. If you want to save this position, first set the position, wait at least 2 seconds and then use packet 8E-A6 to save the position.

Byte	Item	Type	Units
0-3	X-axis	Single	Meters
4-7	Y-axis	Single	Meters
8-11	Z-axis	Single	Meters

Table 29: Command Packet 0x31 Data Format (single precision)

Byte	Item	Type	Units
0-7	X-axis	Double	Meters
8-15	Y-axis	Double	Meters
16-23	Z-axis	Double	Meters

Table 30: Command Packet 0x31 Data Format (double precision)

Command Packet 0x32 Accurate Initial Position (Latitude, Longitude, Altitude)

This packet provides an accurate initial position to the GPS receiver in latitude, longitude, and altitude coordinates. Either the single precision or the double precision version of this packet may be used, however, we recommend using the double precision version for greatest accuracy. The GPS receiver uses this position for performing time-only fixes. If a survey is in progress when this command is issued, the survey is aborted, and this position data is used immediately. The coordinates entered must be in the WGS-84 datum. The Resulution T will automatically switch to the overdetermined timing mode. Note that this position is not automatically saved to Flash memory. If you want to save this position, first set the position, wait at least 2 seconds and then use packet 8E-A6 to save the position.

NOTE: When converting from degreees to radians use the following value for PI.

3.1415926535898

Byte	Item	Type	Units
0-3	Latitude	Single	Radians, north
4-7	Longitude	Single	Radians, east
8-11	Altitude	Single	Meters

Table 31: Command Packet 0 x 32 Data Format (single precision)

Byte	Item	Type	Units
0-7	Latitude	Double	Radians, north
8-15	Longitude	Double	Radians, east
16-23	Altitude	Double	Meters

Table 32: Command Packet 0 x 32 Data Format (double precision)

Command Packet 0x34: Satellite Select For One-Satellite Mode

This packet allows the user to control the choice of the satellite to be used for the one-satellite time-only fix mode. This packet contains one byte. If the byte value is 0, the GPS receiver automatically chooses the best. This automatic selection of the best satellite is the default action, and the GPS receiver does this unless it receives this packet. If the byte value is from 1 to 32, the packet specifies the PRN number of the satellite to be used.

Command Packet 0x35 Set or Request I/O Options

This packet requests the current I/O option states and allows the I/O option states to be set as desired.

To request the option states without changing them, the user sends this packet with no data bytes. To change any option states, the user includes 4 data bytes with the values. The I/O options, their default states, and the byte values for all possible states are shown below. These options can be set into non-volatile memory (FLASH ROM) with the 0x8E-26 command. The GPS receiver returns packet 0x55.

These abbreviations apply to the following table: ALT (Altitude), ECEF (Earth-centered, Earth-fixed), XYZ (Cartesian coordinates), LLA (latitude, longitude, altitude), HAE (height above ellipsoid), WGS-84 (Earth model (ellipsoid)), MSL geoid (mean sea level), and UTC (universal coordinated time).

Byte	Data Type	Bit	Default	Value	Meaning	Associated Packet
0	Position	0	1	0 1	ECEF off ECEF on	0x42 or 0x83
		1	0	0 1	LLA off LLA on	0x4A or 0x84
		2	0	0 1	HAE (datum) MSL geoid (Note 1)	0x4A or 0x84
		3	0	0	reserved	
		4	0	0 1	single-precision position double-precision position	0x42/4A 0x83/84
		5:7	0		reserved	
1	velocity	0	1	0 1	ECEF off ECEF on	0x43
		1	0	0 1	ENU off ENU on	0x56
		2:7	0		reserved	
2	timing	0	0	0 1	GPS time reference UTC time reference	0x42, 0x43, 0x4A, 0x83, 0x84, 0x56,
3	auxiliary	0	0	0 1	packet 5A off packet 5A on	0x5A
		1	0	0	reserved	
		2			reserved	
		3	0	0 1	output AMU output dB/ Hz	0x5A, 0x5C, 0x47
		4:7	reserved	0	0	

Table 33: Command Packet 0 x 35 Data Format

Note 1: When using the MSL altitude output, the current datum must be set to WGS-84.

Command Packet 0x37: Request Status and Values of Last Position

This packet requests information regarding the last position fix (normally used when the GPS receiver is not automatically outputting fixes). The GPS receiver returns the position/ velocity auto packets specified in the 0x35 message as well as message 0x57. This packet contains no data.

Command Packet 0x38: Request Satellite System Data

This packet requests current satellite data.The GPS receiver returns packet 0x58.

Byte	Item	Type	Value	Meaning
0	Operation	UINT8	1	Must always be '1'
1	Type of data	UINT8	2 3 4 5 6	Almanac Health page, toa, WNa Ionosphere UTC Ephemeris
2	Sat PRN#	UINT8	0 1 - 32	Data not satellite ID specific satellite PRN number

Table 34: Command Packet 0 x 38 Data Format

Command Packet 0x39: Set or Request SV Disable and Health Use

Normally the GPS receiver selects only healthy satellites (based on transmitted values in the ephemeris and almanac) which satisfy all mask values. This packet allows overriding the internal logic and forces the receiver to either unconditionally disable a particular satellite or to ignore a bad health flag. The GPS receiver returns packet 0x59 if operation 3 or 6 is requested; otherwise there is no reply.

It should be noted that when viewing the satellite disables list, the satellites are not numbered but are in numerical order. The disabled satellites are signified by a "1" and enabled satellites are signified by a "0".

Byte	Item	Type	Value	Meaning
0	Operation	UINT8	1 2 3 4 5 6	Enable satellite (default) Disable satellite Request enable/disable status of all 32 satellites Heed health (default) Ignore health Request heed - or - ignore health on all 32 satellites
1	Satellite #	UINT8	0 1 - 32	All 32 satellites Any one satellite PRN number

Table 35: Command Packet 0 x 39 Data Format

Note: At power-on and after a reset the default values are set for all satellites.

Caution: Improperly ignoring health can cause the GPS receiver software to lock up, as an unhealthy satellite may contain defective data. Use extreme caution in ignoring satellite health.

Command Packet 0x3A: Request last raw Measurement

This packet requests the most recent raw measurement data for one specified satellite. The GPS receiver returns packet 0x5A if data is available.

Byte	Item	Type	Value	Meaning
0	satellite number	INT8	0 1-32	all satellites in current tracking set specific desired satellite

Table 36: Command Packet 0 x 3A Data Format

Command Packet 0x3C: Request Current Satellite Tracking Status

This packet requests the current satellite tracking status. The GPS receiver returns packet 0x5C if data is available.

Byte	Item	Type	Value	Meaning
0	satellite number	INT8	0 1-32	all satellites in current tracking set specific desired satellites

Table 37: Command Packet 0 x 3C Data Format

Command Packet 0x7A: Set or Request NMEA Interval and Message Mask

The NMEA message determines whether or not a given NMEA message will be output. If the bit for a message is set, the message will be sent every "interval" seconds. To determine the NMEA interval and message mask, use the values shown in Table A-21. While fixes are being generated the output order is: ZDA, GGA, GLL, VTG, GSA, GSV, RMC.

Byte	Bit	Item	Type	Value	Meaning
0		Subcode	UINT8	0	
1		Interval	UINT8	1-225	Fix interval in seconds
2		Reserved	UINT8	0	
3		Reserved	UINT8	0	
4	0	RMC	Bit	0 1	On Off
5	1-7	Reserved	Bit	0	
5	0	GGA	Bit	0 1	On Off
5	1	GGL	Bit	0 1	On Off
5	2	VTG	Bit	0 1	On Off
5	3	GSV	Bit	0 1	On Off
5	4	GSA	Bit	0 1	On Off
5	5	ZDA	Bit	0 1	On Off
5	6-7	Reserved	Bit	0	

Table 38: Command Packet 0 x 7A Data Format

Report Packet 0x7B: Set NMEA Message Output

This packet is sent in response to command packet 7A and has the same data format as packet 7A.

Report Packet 0x42: Single-precision Position Fix

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O "position" option is set to "XYZ ECEF" and the I/O Precision-of-Position output" is set to single-precision, then the GPS receiver sends this packet each time a fix is computed and at start-up. The data format is shown below.

Byte	Item	Type	Units
0-3	X	Single	meters
4-7	Y	Single	meters
8-11	Z	Single	meters
12-15	time-of-fix	Single	seconds

Table 39: Report Packet 0 x 42 Data Format

The time-of-fix is in GPS time or UTC as selected by the I/O "timing" option in command packet 0x35. Packet 0x83 provides a double-precision version of this information.

Report Packet 0x43 Velocity Fix, XYZ ECEF

This packet provides current GPS velocity fix in XYZ ECEF coordinates. If the I/O "velocity" option (packet 0x35) is set to "XYZ ECEF, then the GPS receiver sends this packet each time a fix is computed or in response to packet 0x37. The data format is shown below. The time-of-fix is in GPS or UTC as selected by the I/O "timing" option.

Byte	Item	Type	Units
0-3	X velocity	Single	meters/second
4-7	Y velocity	Single	meters/second
8-11	Z velocity	Single	meters/second
12-15	bias rate	Single	meters/second
16-19	time-of-fix	Single	seconds

Table 40: Report Packet 0 x 43 Data Format

Report Packet 0x45: Software Version Information

This packet provides information about the version of software in the Resolution T. The GPS receiver sends this packet after power-on and in response to packet 0x1F.

Byte	Item	Type
0	Major version number of application	UINT8
1	Minor version number	UINT8
2	Month	UINT8
3	Day	UINT8
4	Year number minus 1900	UINT8
5	Major revision number of GPS core	UINT8
6	Minor revision number	UINT8
7	Month	UINT8
8	Day	UINT8
9	Year number minus 1900	UINT8

Table 41: Report Packet 0 x 45 Data Format

Note: Bytes 0 though 4 are part of the application layer of the firmware, while bytes 5 through 9 are part of the GPS core layer of the firmware.

Report Packet 0x47: Signal Level for All Satellites Tracked

This packet provides received signal levels for all satellites currently being tracked or on which tracking is being attempted (i.e., above the elevation mask and healthy according to the almanac). The receiver sends this packet only in response to packet 0x27. The data format is shown below.Up to 12 satellite number/signal level pairs may be sent, indicated by the count field. Signal level is normally positive. If it is zero then that satellite has not yet been acquired. If it is negative then that satellite is not currently in lock. The absolute value of signal level field is the last known signal level of that satellite.

Byte	Item	Type
0	count	UINT8
1	satellite number 1	UINT8
2- 5	signal level 1	Single
6	satellite number 2	UINT8
7-10	signal level 2	Single
(etc.)	(etc.)	(etc.)

Table 42: Report Packet 0 x 47 Data Format

Note: The signal level provided in this packet is a linear measure of the signal strength after correlation or de-spreading. Units, either AMU or dB/Hz, are controlled by packet 0x35.

Report Packet 0x4A: Single Precision LLA Position Fix

The packet provides current GPS position fix in LLA (latitude, longitude, and altitude) coordinates. If the I/O position option is set to "LLA" and the I/O precision of position output is set to single precision, then the receiver sends this packet each time a fix is computed. The data format is shown below:

Byte	Item	Type	Units
0-3	latitude	Single	radians: + for north, - for south
4-7	longitude	Single	radians: + for east, - for west
8-11	altitude	Single	meters
12-15	clock Bias	Single	meters (always relative to GPS)
16-19	time of fix	Single	seconds

Table 43: Report Packet 0 x 4A Single Precision LLA Position Fix

The LLA conversion is done according to the datum selected using packet 8E-15. The default is WGS-84. Altitude is referred to the datum or the MSL Geoid, depending on which I/O LLA altitude option is selected with packet 0x35. The time of fix is in GPS time or UTC, depending on which I/O timing option is selected.

CAUTION: When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant π (pi). The value of a constant π as specified in ICD-GPS-200 is 3.1415926535898.

CAUTION: The MSL option is only valid with the WGS-84 datum. When using other datums, only the HAE option is valid.

Report Packet 0x55 I/O Options

This packet provides the current I/O option states in response to packet 0x35 request. The data format is the same as for packet 0x35 and is repeated below for convenience.

These abbreviations apply to the following table: ALT (Altitude), ECEF (Earth-centered, Earth-fixed), XYZ (Cartesian coordinates), LLA (latitude, longitude, altitude), HAE (height above ellipsoid), WGS-84 (Earth model (ellipsoid)), MSL geoid (Earth (mean sea level) mode), and UTC (coordinated universal time).

Byte	Data Type	Bit	Default	Value	Meaning	Associated Packet
0	UINT8 Position	0	1	0 1	ECEF on ECEF off	0x42 or 0x83
		1	0	0 1	LLA off LLA on	0x4A or 0x84
		2	0	0 1	HAE (datum) MSL geoid	0x4A or 0x84
		3	0	0	reserved	
		4	0	0 1	single-precision position double-precision position	0x42/4A 0x83/84
		5:7	0		reserved	
1	UINT8 velocity	0	1	0 1	ECEF off ECEF on	0x43
		1	0	0 1	ENU off ENU on	0x56
		2:7	0		reserved	
2	UINT8 timing	0	0	0 1	GPS time reference UTC time reference	0x42, 0x43, 0x4A, 0x83, 0x84, 0x56,
3	UINT8 auxiliary	0	0	0 1	packet 5A off packet 5A on	0x5A
		1	0	0 1	raw PR's in 5A filtered PR's in 5A	0x5A
		2	reserved			
		3	0	0 1	output AMU output dB/ √Hz	0x5A, 0x5C, 0x47
		4:7	reserved	0	0	

Table 44: Report Packet 0 x 55 Data Format

Report Packet 0x56: Velocity Fix, East-North-Up (ENU)

If East-North-Up (ENU) coordinates have been selected for the I/O "velocity" option, the receiver sends this packet under the following conditions:

- Each time that a fix is computed
- In response to packet 0x37 (last known fix)
- The data format is shown below.

Byte	Item	Type	Units
0-3	East Velocity	Single	m/s; + for east, - for west
4-7	North Velocity	Single	m/s; + for north, - for south
8-11	up velocity	Single	m/s; + for up, - for down
12-15	clock bias rate	Single	m/s
16-19	time-of-fix	Single	seconds

Table 45: Report Packet 0 x 56 Data Format

Note: The time-of-fix is in GPS or UTC time as selected by the I/O "timing" option.

Report Packet 0x57: Information about Last Computed Fix

This packet provides information concerning the time and origin of the previous position fix. The receiver sends this packet, among others, in response to packet 0x37. The data format is shown below.

Byte	Item	Type	Value	Meaning
0	source of info	UINT8	0 1 2 4 5 6 8	none regular fix initialization diagnostic initialization diagnostic entered by 0x23 or 0x2B entered by 0x31 or 0x32 default after BBRAM fail
1	Tracking mode	UINT8	0 1 2 3 4 5 6	No previous fix Time only 1-SV 2D clock hold 2D 3D overdetermined clock DGPS reference
2-5	time of last fix	Single		seconds GPS time
6-7	week of last fix	UINT16		weeks

Table 46: Report Packet 0 x 57 Data Format

Report Packet 0x58: GPS System Data/Acknowledge from Receiver

This packet provides GPS data (almanac, ephemeris, etc.). The receiver sends this packet in response to packet 0x38. The data format is shown below. The table and section numbers refered to in the “Meaning” column reference the “Global Positioning System Standard Positioning Service Signal Specification” document.

Byte	Item	Type	Value	Meaning
0	operation	UINT8	2 3	data out no data on SV
1	Type of data	UINT8	2 3 4 5 6	Almanac Health page, T_oa, WN_oa Ionosphere UTC Ephemeris
2	Sat PRN #	UINT8	0 1 to 32	Data that is not satellite ID-specific Satellite PRN number
3	Length (n)	UINT8		byte count
4 to n+3	Data			

Table 47: Report Packet 0 x 58 Data Format

Note: If data is not available, byte 3 is set to 0 and “no” data is sent.

Byte	Item	Type	Value	Meaning (see note)
4	T_{oa} (raw)	UINT8		Table 2.8
5	SV_HEALTH	UINT8		
6-9	e	Single		
10-13	t_{oa}	Single		
14-17	i_o	Single		
18-21	OMEGADOT	Single		
22-25	sqrt(A)	Single		
26-29	$(OMEGA)_0$	Single		
30-33	(OMEGA)	Single		
34-37	M_0	Single		
38-41	a_{f0}	Single		
42-45	a_{f1}	Single		
46-49	Axis	Single		
50-53	n	Single		
54-57	OMEGA_n	Single		Derived
58-61	ODOT_n	Single		Derived
62-65	t_{zc}	Single		time of collection (set to –1.0 if there is no data available)
66-67	week number	UINT16		GPS week number
68-69	WN_a	UINT16		Sec 2.4.5.2.3

Table 48: Report Packet 0 x 58 Almanac Data Type 2

Note: All angles are in radians.

Byte	Item	Type	Meaning
4	week number for health	UINT8	Sec 2.4.5.3
5-36	SV health	UINT8	Sec 2.4.5.3
37	t_{oa} for health	UINT8	Sec 2.4.5.2.3
38	current t_{oa}	UINT8	time of collection
39-40	current week number	UINT16	time of collection

Table 49: Report Packet 0 x 58 Almanac Health Data Type 3

Byte	Item	Type	Meaning
4-11	not used		
12-15	α_0	Single	Sec 2.4.5.6
16-19	α_1	Single	
20-23	α_2	Single	
24-27	α_3	Single	
28-31	β_0	Single	
32-35	β_1	Single	
36-39	β_2	Single	
40-43	β_3	Single	

Table 50: Report Packet 0 x 58 Ionosphere Data Type 4

Byte	Item	Type	Meaning
4-16	not used		
17-24	A_0	Double	Sec 2.4.5.5
25-28	A_1	Single	
29-30	Δt_{LS}	SINT16	
31-34	t_{ot}	Single	
35-36	WN_t	UINT16	
37-38	WN_{LSF}	UINT16	
39-40	DN	UINT16	
41-42	Δt_{LSf}	SINT16	

Table 51: Report Packet 0 x 58 UTC Data Type 5

Byte	Item	Type	Meaning
4	SV number	UINT8	SV PRN number
5-8	t_ephem	Single	time of collection (seconds)
9-10	week number	UINT16	GPS week number 0 thru 1023
11	retired		
12	retired		
13	SV accuracy raw	UINT8	URA index of SV (0 thru 15)
14	SV health	UINT8	6 bit health code
15-16	IODC	UINT16	Issue of data clock
17-20	t_{GD}	Single	L1-L2 correction term
21-24	t_{oc}	Single	Sec 20.4.3.5
25-28	a_{f2}	Single	Sec 2.4.3.6
29-32	a_{f1}	Single	
33-36	a_{fo}	Single	
37-40	SV accuracy	Single	URA of SV
41	IODE	UINT8	issue of data

Byte	Item	Type	Meaning
			ephemeris
42	retired		Table 2-5
43-46	C_{rs}	Single	
47-50	Δn	Single	
51-58	M_0	Double	
59-62	C_{uc}	Single	
63-70	e	Double	
71-74	C_{US}	Single	
75-82	sqrt(A)	Double	
83-86	t_{oe}	Single	
87-90	C_{ic}	Single	
91-98	$(OMEGA)_0$	Double	
99-102	C_{is}	Single	
103-110	i_o	Double	
111-114	C_{rc}	Single	
115-122	(OMEGA)	Double	
123-126	OMEGADOT	Single	
127-130	IDOT	Single	
131-138	Axis	Double	
139-146	n	Double	
147-154	r1me2	Double	= $\mathrm{sqrt}(1.0-e^2)$
155-162	OMEGA_n	Double	derived from OMEGA_0, OMEGADOT
163-170	ODOT_n	Double	derived from OMEGADOT

Table 52: Report Packet 0 x 58 Ephemeris Data Type 5

Note: All angles are in radians. Reference numbers refer to “Global Positioning System Standard Positioning Service Signal Specification.” As of this writing, it is available in Adobe Acrobat format at http://www.navcen.uscg.gov/pubs/gps/sigspec/

Report Packet 0x59: Status of Satellite Disable or Ignore Health

This packet is sent in response to command packet 0x39.

Byte	Item	Type	Value	Meaning
0	Operation	UINT8	3	The remaining bytes tell whether receiver is allowed to select each satellite.
			6	The remaining bytes tell whether the receiver heeds or ignores each satellite's health as a criterion for selection.
1 to 32	Satellite #	UINT8 (1 per SV)	0	Enable satellite selection or heed satellite's health. Default value.
			1	Disable satellite selection or ignore satellite's health.

Table 53: Report Packet 0 x 59 Data Format

Report Packet 0x5A Raw Data Measurement Data

Packet 0x5A provides raw GPS measurement data. If the packet 0x35 auxiliary option byte bit 1 is set, this packet is sent automatically as measurements are taken.

Byte	Item	Type	Units
0	SV PRN number	UINT8	
1-4	sample length	single	milliseconds
5-8	signal level	single	AMU or dB/Hz
9-12	code phase	single	1/16th chip
13-16	doppler	single	Hertz @ L1
17-24	time of measurement	double	seconds

Table 54: Report Packet 0 x 5A Data Format

Notes: The sample length is the number of milliseconds over which the sample was averaged.

The code phase value is the average delay over the sample interval of the received C/A code, and is measured with respect to the receiver's millisecond timing reference.

Report Packet 0x5C Satellite Tracking Status

The receiver sends this packet in response to command packet 0x3C.

Byte	Bit	Item	Type	Value	Meaning
0		SV PRN number	UINT8	1-32	PRN
1	0:2	slot number	bit field	0 0 0	not used
1	3:7	channel number	bit field	0 0 0 0 0 0 0 1 0 0 1 0 0 0 1 1 0 1 0 0 0 1 0 1 0 1 1 0 0 1 1 1 1 0 0 0 1 0 0 1 1 0 1 0 1 0 1 1	channel 1 channel 2 channel 3 channel 4 channel 5 channel 6 channel 7 channel 8 channel 9 channel 10 channel 11 channel 12
2		acquisition flag	UNIT8	0 1 2	never acquired acquired re-opened search
3		ephemeris flag	UNIT8	0 >0	flag not set good ephemeris
4-7		signal level	Single		AMU or dB/Hz
8-11		time of last measurement	Single	secs	GPS time of week
12-15		elevation angle	single		radians
16-19		azimuth angle	single		radians
20		old measurement flag	UINT8	0 >0	flag not set measurement old
21		integer msec flag	UINT8	0 1 2 3 4	don’t know msec known from subframe verified by bit crossing verified by good fix

Byte	Bit	Item	Type	Value	Meaning
					suspect msec error
22		bad data flag	UINT8	0	flag not set
				1	bad parity
				2	bad ephemeris health
23		data collection flag	UINT8	0	flag not set
				>0	collection in progress

Table 55: Report Packet 0 x 5C Data Format

Report Packet 0x6D All-in-View Satellite Selection

This packet provides a list of satellites used for position or time only fixes by the GPS receiver. The packet also provides the PDOP, HDOP, and VDOP of that set and provides the current mode (automatic or manual, 3-D or 2-D, overdetermined, clock, etc.). This packet has variable length equal to 17+nsvs where "nsvs" is the number of satellites used in the solution. If an SV is rejected for use by the T-RAIM algoritm then the SV PRN value will be negative.

The GPS receiver sends this packet in response to packet 0x24 when the selection list is updated. If enabled with packet 8E-A5, the reeiver will send this packet whenever the selection is updated. The data format is shown below.

Byte	Bit	Item	Type	Value	Meaning
0	0:2	fix dimension	bit field	1	1D clock fix
				3	2D fix
				4	3D fix
				5	OD clock fix
	3	fix mode	bit field	0	auto
				1	manual
	4:7	number of sv's in fix	bit field	0-12	count
1-4		PDOP	Single		PDOP
5-8		HDOP	Single		HDOP
9-12		VDOP	Single		VDOP
13-16		TDOP	Single		TDOP
17 - n		SV PRN	SINT8	+/- (1-32)	PRN

Table 56: Report Packet 0 x 6D Data Format

Report Packet 0x83: Double Precision XYZ

This packet provides current GPS position fix in XYZ ECEF coordinates. If the I/O “position” option is set to “XYZ ECEF” and the I/O double position option is selected, the receiver sends this packet each time a fix is computed. The data format is shown below.

Byte	Item	Type	Units
0-7	X	Double	meters
8-15	Y	Double	meters
16-23	Z	Double	meters
24-31	clock bias	Double	meters
32-35	time-of-fix	Single	seconds

Table 57: Report Packet 0 x 83 Data Format

Note: The time-of-fix is in GPS time or UTC, as selected by the I/O “timing” option. Packet 0x42 provides a single-precision version of this information.

Report Packet 0x84: Double Precision LLA Position Fix and Bias Information

This packet provides current GPS position fix in LLA coordinates. If the I/O "position" option is set to "LLA" and the double position option is selected (see packet 0x35), the receiver sends this packet each time a fix is computed.

Byte	Item	Type	Units
0-7	latitude	Double	radians; + for north, - for south
8-15	longitude	Double	radians; + for east, - for west
16-23	altitude	Double	meters
24-31	clock bias	Double	meters (always relative to GPS)
32-35	time-of-fix	Single	seconds

Table 58: Report Packet 0 x 84 Data Format

NOTE: The time-of-fix is in GPS time or UTC time as selected by the I/O "timing" option.

CAUTION: When converting from radians to degrees, significant and readily visible errors will be introduced by use of an insufficiently precise approximation for the constant p (PI). The value of the constant PI as specified in ICD-GPS-200 is 3.1415926535898.

Command Packet 0xBB Set Primary Configuration

In query mode, packet 0xBB is sent with a single data byte and returns report packet 0xBB in the format shown below.

Byte	Item	Type	Value	Meaning	Default
0	Subcode	UINT8	0	Query mode	

Table 59: Command Packet 0 x BB Data Format (Query Only)

TSIP packet 0xBB is used to set GPS Processing options. The table below lists the individual fields within the 0xBB packet.

Byte	Item	Type	Value	Meaning	Default
0	Subcode	UINT8	0xFF	Primary receiver configuration block	
1	receiver mode	UINT8	0 1 3 4 5 6 7	automatic single satellite (1 SV) Horizontal (2D) Full position (3D) DGPS reference 2D clock hold over-determined clock	#4 (3D)
2	reserved	UINT8	OxFF	**do not alter**	
3	Dynamics Code	UINT8	1 2 3 4	Land Sea Air Stationary	Land
4	reserved	UINT8	0xFF	**do not alter**	
5-8	Elevation Mask	Single	0-π/2	Lowest satellite elevation for fixes (radians)	10 degrees
9-12	AMU Mask	Single		Minimum signal level for fixes	4
13-16	PDOP Mask	Single		Maximum DOP for fixes	12
17-20	PDOP Switch	Single		Switches 2D/3D mode	6
21	reserved	UINT8	0xFF	**do not alter**	
22	Foliage Mode	UINT8	0 1 2	Never Sometimes Always	sometimes
23	reserved	UINT8	OxFF	**do not alter**	
24	reserved	UINT8	OxFF	**do not alter**	
25	reserved	UINT8	OxFF	**do not alter**	
26	reserved	UINT8	OxFF	**do not alter**	
27-39	reserved	UINT8	OxFF	**do not alter**	

Table 60: Report Packet 0 x BB Data Format

CAUTION: The operation of the Resolution T can be affected adversely if incorrect data is entered in the fields associated with packet 0xBB. Know what you are doing.

NOTE: When sending packet 0xBB, fields that are specified as "do not alter" or if you do not want to alter a specific field, send a value of 0xFF for UINT8 types and a value of –1.0 for floating poin types. The Resolution T will ignore these values.

Command Packet 0xBC Set Port Configuration

TSIP packet 0xBC is used to set and query the port characteristics. In query mode, packet 0xBC is sent with a single data byte and returns report packet 0xBC. Note that the input and output baud rates must be the same.

Byte	Item	Type	Value	Meaning
0	Port Number	UINT8	0 1 FF	Port 1 (standard) Port 2 (not available) Current port

Table 61: Command Packet 0 x BC Data Format (Query Mode)

The table below lists the individual fields within the packet 0xBC when used in the set mode and when read in the query mode.

Byte	Item	Type	Value	Meaning
0	Port to Change	UINT8	0 1 0xFF	Port 1 (standard) Port 2 (factory only) Current port
1	Input Baud Rate	UINT8	0 1 2 3 4 5 6 7 8 9 10 11	None None 300 baud 600 baud 1200 baud 2400 baud 4800 baud 9600 baud 19200 baud 38400 baud 57600 baud 115200 baud
2	Output Baud Rate	UINT8	As above	As above
3	# Data Bits	UINT8	2 3	7 bits 8 bits
4	Parity	UINT8	0 1 2	None Odd Even
5	# Stop Bits	UINT8	0 1	1 bit 2 bits
6	Flow Control	UINT8	0	none
7	Input Protocols	UINT8	0 2	none TSIP
8	Output Protocols	UINT8	0 2 4	none TSIP NMEA
9	Reserved	UINT8	0	

Table 62: Command and Report Packet 0 x BC Field Data Format

TSIP Superpackets

Several packets have been added to the core TSIP protocol to provide additional capability for the receivers. In packets 0x8E and their 0x8F responses, the first data byte is a subcode which indicates the superpacket type. For example, in packet 0x8E-15, 15 is the subcode that indicates the superpacket type. Therefore the ID code for these packets is 2 bytes long followed by the data.

Command Packet 0x8E-15 Request current Datum values

This packet contains only the subpacket ID, 0x15. The response to this packet is 8F-15

Command Packet 0x8E-26: Write Receiver Configuration to Flash ROM

This command packet causes the current configuration settings to be written to the flash ROM. This packet contains only a single byte: the sub-packet ID. Note that the unit will reset itself following the execution of this command.

Command Packet 0x8E-41: Request Manufacturing Parameters

This packet is used to request the manufacturing parameters stored in nonvolatile memory.Send this packet with no data bytes (don't forget the subcode) to request packet 0x8F-41.

Command Packet 0x8E-42: Stored Production Parameters

This packet is used to request the production parameters stored in nonvolatile memory. Send this packet with no data bytes (don't forget the subcode) to request packet 0x8F-42.

Command Packet 0x8E-4A: Set PPS Characteristics

This packet allows the user to query (by sending the packet with no data bytes) or set the Resolution T PPS characteristics. The Resolution T responds to a query or set command with packet 8F-4A.

Byte	Item	Type	Value	Meaning
0	Subcode	UINT8	0x4A	
1	PPS driver switch	UINT8	0 1	off on
2	reserved	UINT8		
3	PPS polarity	UINT8	0 1	positive negative
4-11	PPS offset or cable delay (see note)	Double		seconds
12-15	Bias uncertainty threshold	Single		meters

Table 63: Command and Report Packet 0 x 8E-4A Data Format

Note: Negative offset values advance the PPS, and are normally used to compensate for cable delay.

Command Packet 0x8E-4E: Set PPS output option

This command packet sets the PPS driver switch to one of the values listed in Table A-52. The current driver switch value can be requested by sending the packet with no data bytes except the subcode byte.

Driver switch values 3 and 4 only make sence in Overdetermined Timing mode. In any position fix mode the effective choicds are always on or during fixes which you get if you set the driver switch to 3 or 4.

The Resolution T can also be configured to generate an Even Second pulse in place of the PPS pulse by setting the value as shown in the table below.

Byte	Item	Type	Value	Meaning
0	Subcode	UINT8	0x4E	
1	PPS driver switch	UINT8	2	PPS is always on. PPS is generated every second
			3	PPS is output when at least one satellite is tracking. PPS is generated every second
			4	PPS is output when at least three satellites are tracking. PPS is generated every second
			130	PPS is always on. PPS is generated every even second
			131	PPS is output when at least one satellite is tracking. PPS is generated every even second
			132	PPS is output when at least three satellites are tracking. PPS is generated every even second

Table 64: Command Packet 0 x 8E-4E Data Format

Command Packet 0x8E-A2: UTC/GPS Timing

Command packet 8E-A2 sets the UTC/GPS timing mode (time and date fields) in packet 0x8F-AB, and the temporal location of the Resolution T output PPS. Send packet 8E-A2 with no data to request the current settings. The Resolution T replies with response packet 8F-A2.

Byte	Bit	Item	Type	Value	Meaning
0		Subcode	UINT8	0xA2	
1	0	UTC/GPS time	bit field	0 1	GPS time/date in packet 0x8F-AB UTC time/date in packet 0x8F-AB
	1		bit field	0 1	PPS referenced to GPS time PPS referenced to UTC time

Table 65: Command Packet 0 x 8E-A2 Data Format

Command Packet 0x8E-A4 Test Modes

The Resolution T provides a test mode of operation that allows the user to set the time and UTC parameters. Packet 0x8F-AC provides a status bit (minor alarm bit 8) to warn the user that the Resolution T is operating in a test mode. There is no response to this packet.

Note that test mode 3 does not actually cause the Resolution T to enter a test mode, but instead provides a means for the user to send UTC parameters to the Resolution T that will be used in test mode 1.

Test Mode 0 Data Fields:

Test Mode: Set this field to 0 to exit test mode and return the Resolution T to normal operations. A reset or power cycle will also cause the Resolution T to exit test mode.

Test Mode 1 Data Fields:

Test Mode: Setting this field to 1 tells the Resolution T to enter the user time test mode. The Resolution T will set the time to the week number and TOW sent with this packet. The Resolution T will then increment this time once per second. The time in packets 8F-AB and 8F-A7 will show the user test time, but all other packets that have time fields will be unaffected.

Week Number: This field contains the week number for the user time test mode.

Time-of-Week: This field contains the TOW for the user time test mode.

Test Mode 3 Data Fields:

Note: For a more detailed description of UTC parameters GPS SPS Signal Specification

Test Mode: Setting this field to 3 tells the Resolution T that the following fields contain the user UTC parameters that are to be used while in test mode 1.

A_0: This field is the fractional second offset of GPS from UTC at the reference time in seconds.

A_1: This field is the rate of change of fractional second offset of GPS from UTC in seconds/second.

delta_t_LS: Current integer leap seconds

t_ot: This field is the reference time-of-week for the A_0/A_1 parameters.

WN_t: This field is the reference week number for the A_0/A_1 parameters.

WN_LSF: This field is the week number of a future leap second event

DN: This field is the day number of a future leap second event.

delta_t_LSF: This field is the integer number of future leap seconds.

Byte	Item	Type	Description
0	Subcode	UINT8	0xA4
1	Test Mode	UINT8	0 = Exit test mode

Table 66: Command Packet 0 x 8E-A4 Test Mode 0 Data Format

Byte	Item	Type	Description
0	Subcode	UINT8	0xA4
1	Test Mode	UINT8	1 = Set absolute time, ignore GPS time
2-3	Week Number	UINT16	Week number (0-1023)
4-7	Time of Week	UINT32	Seconds (0-604799)

Table 67: Command Packet 0 x 8E-A4 Test 1 Mode 1Data Format

Byte	Item	Type	Description
0	Subcode	UINT8	0xA4
1	Test Mode	UINT8	3 = Send user UTC parameter
2-5	A_0	Single	Seconds
6-9	A_1	Single	Seconds/second
10-11	delta_t_LS	SINT16	Seconds
12-15	t_ot	UINT32	Seconds
16-17	WN_t	UINT16	Week number
18-19	WN_LSF	UINT16	Week number
20-21	DN	UINT16	Day number (1-7)
22-23	delta_t_LSF	SINT16	Seconds

Table 68: Command Packet 0 x 8E-A4 Test Mode 3 Data Format

Command Packet 0x8E-A5: Packet Broadcast Mask

Use command packet 8E-A5 to set the packet broadcast masks or to request the current mask settings. The Resolution T replies to requests with response packet 8F-A5. The broadcast mask is bitwise encoded to allow the user to turn on and off the broadcast of certain packets. For those broadcast packets that have multiple format, the Resolution T will broadcast only one of the formats. If more than one of the formats is masked on for broadcast, then the format with the greatest precision of content masked on will be sent and the rest will not. For each bit in the mask that is used, the coding is as follows:

0: Turn off broadcast of this packet

1: Turn on broadcast of this packet

Byte	Bit	Item	Type	Description
0		Subcode	UINT8	0xA5
1-2	0 1 2 3 4 5 6	Mask 0	bit field	8F-AB, Primary Timing Information Reserved 8F-AC, Supplemental Timing Information Reserved Reserved Reserved Automatic Output Packets
3-4		Mask 2	bit field	reserved

Table 69: Command and Report Packet 0 x 8E-A5 Data Format

Command Packet 0x8E-A6 Self-Survey Command

Use command packet 8E-A6 to issue a self-survey command, to save the current position in Flash or to delete the position saved in Flash. There is no response to this packet.

Byte	Item	Type	Value	Meaning
0	Subcode	UINT8	0xA6	
1	self-survey command	UINT8	0 1 2	Restart self-survey Save position to Flash Delete position from Flash

Table 70: Command and Report Packet 0 x 8E-A6 Data Format

Command Packet 0x8E-A9: Self-Survey Parameters

Use command packet 8E-A9 to set the self-survey parameters or to request the current settings. The Resolution T replies to requests with response packet 8F-A9.

Data Fields

Self-Survey Enable: Use this field to enabled or disabled the self-survey mechanism.

- 0: Disable the self-survey mechanism
- 1: Enable the self-survey mechanism

Position Save Flag: Use this field to tell the self-survey mechanism to automatically save (or to not save) the self-surveyed position at the end of the self-survey procedure.

- 0: Don’t automatically save the surveyed position when the self-survey is complete
- 1: Automatically save the surveyed position when the self-survey is complete.

Self-Survey Length: Use this field to specify the number of position fixes that are to be averaged together to form the self-surveyed position used for clock-only fixes.

- Limits: 1 to (2^{32} - 1) fixes

Byte	Item	Type	Value	Description
0	Subcode	UINT8	0xA9	
1	Self-Survey Enable	UINT8	0 1	Disabled enabled
2	Position Save Flag	UINT8	0 1	don't save position save self-surveyed position at the end of the survey
3-6	Self-Survey Length	UINT32	see above	Number of fixes
7-10	Reserved	UINT32	0	0

Table 71: Command Packet 8E-A9 Data Format

Report Packet 0x8F-15 Current Datum Values

This packet contains 43 data bytes with the values for the datum currently in use and is sent in response to packet 8E-15. If a built-in datum is being used, both the datum index and the five double-precision values for that index are returned. If the receiver is operating on a custom user-entered datum, the datum index is set to –1 and the five values are displayed. These five values describe an elipsoid to convert ECEF XYZ coordinate system into LLA.

Byte	Type	Value	Description
0	Super Packet ID	14	
1-2	Datum index (-1 for custom)	Datum Index	
3-10	DOUBLE	DX	meters
11-18	DOUBLE	DY	meters
19-26	DOUBLE	DZ	meters
27-34	DOUBLE	A-axis	meters
35-42	DOUBLE	Eccentricity squared	none

Table 72: Datums

Report Packet 0x8F-41: Stored Manufacturing Operating Parameters

This packet is sent in response to a command 0x8E-41.

Byte	Item	Type	Units
0	Subcode	UINT8	0x41
1-2	board serial number prefix	SINT16	
3-6	Board serial number	UINT32	
7	Year of build	UINT8	
8	Month of build	UINT8	
9	Day of build	UINT8	
10	Hour of build	UINT8	
11-14	Oscillator offset	Single	
15-16	Test code identification number	UINT16	

Table 73: Stored Manufacturing Operating Parameters

Report Packet 0x8F-42: Stored Production Parameters

This packet is sent in response to 0x8E-42.

Byte	Item	Type	Units
0	Subcode	UINT8	0x42
1	Production options prefix	UINT8	
2	Production number extension	UINT8	
3-4	Case serial number prefix	UINT16	
5-8	Case serial number	UINT32	
9-12	Production number	UINT32	
13-14	Reserved	UINT16	
15-16	Machine identification number	UINT16	
17-18	Reserved	UINT16	

Table 74: Stored Production Parameter

Report Packet 0x8F-4A: Set PPS Characteristics

This is sent in response to a query by packet 0x8E-4A. See the corresponding command packet for information about the data format.

Report Packet 0x8F-4E: PPS Output

This report packet is output after the command packet 8E-4E has been executed. See the corresponding command packet for information about the data format.

Report Packet 0x8F-A2: UTC/GPS Timing

This packet is sent in response to command packet 0x8E-A2. See the corresponding command packet for information about the data format.

Report Packet 0x8F-A5: Packet Broadcast Mask

This packet is sent in response to 0x8E-A5 command and describes which packets are currently automatically broadcast. A ’0’ in a bit field turns off broadcast, and a ’1’ in a bit field enables broadcast. See the corresponding command packet for information about the data format.

Report Packet 0x8F-A9: Self-Survey Parameters

Packet 0x8F-A9 is sent in response to command packet 0x8E-A9 and describes the current self-survey parameters. See the corresponding command packet for information about the data format.

Report Packet 0x8F-AB: Primary Timing Packet

This broadcast packet provides time information once per second. GPS week number, GPS time-of-week (TOW), UTC integer offset, time flags, date and time-of-day (TOD) information is provided. This packet cannot be requested. If enabled, this packet will begin transmission within 20 ms after the PPS pulse to which it refers.

Data Fields

Time of Week: This field represents the number of seconds since Sunday at 00:00:00 GPS time for the current GPS week. Time of week is often abbreviated as TOW.

Week Number: This field represents the current GPS week number. GPS week number 0 started on January 6, 1980.

UTC Offset: This field represents the current integer leap second offset between GPS and UTC according to the relationship: Time (UTC) = Time (GPS) - UTC Offset. The UTC offset information is reported to Resolution T by the GPS system and can take up to 12.5 minutes to obtain. Before the Resolution T has received UTC information from the GPS system, it is only capable of representing time in the GPS time scale, and the UTC offset will be shown as 0.

Timing Flags: This field is bitwise encoded to provide information about the timing outputs. Unused bits are should be ignored.

Bit 0: When 0, the date and time fields broadcast in packet 8F-AB are in the GPS time scale. When 1, these fields are in the UTC time scale and are adjusted for leap seconds. Use command packet 8E-A2 to select either GPS or UTC time scales.

Bit 1: When 0, the PPS output is aligned to GPS. When 1, the PPS output is aligned to UTC. Use command packet 8E-A2 to select either GPS or UTC PPS alignment.

- Bit 2: When 0, time has been set from GPS. When 1, time has net yet been set from GPS.
- Bit 3: When 0, UTC offset information has been received. When 1, UTC offset information is not yet known.
- Bit 4: When 0, time is coming from GPS. When 1, the Resolution T is in a test mode and time is being generated by the test mode selected by the user. See packet 8E-A4, Test Modes.

Time of Day: The time of day is sent in hours-minutes-seconds format and varies from 00:00:00 to 23:59:59, except when time is in UTC and a leap second insertion occurs. In this case the time will transition from 23:59:59 to 23:59:59 to 00:00:00. Use command packet 8E-A2 to select either the GPS or UTC time scale.

Date: The date is sent in day-month-year format. Use command packet 8E-A2 to select either the GPS or UTC time scale.

Broadcast Control: Packet 0x8E/8F-A5, Mask 0, Bit 0

Byte	Bit	Item	Type	Value	Description
0		Subcode	UINT8		0xAB
1-4		time of week	UINT32		GPS seconds of week
5-6		Week Number	UINT16		GPS Week Number (see above)
7-8		UTC Offset	SINT16		UTC Offset (seconds)
9	0 1 2 3 4	timing Flag	bit field	0 1 0 1 0 1 0 1 0 1	GPS time UTC time GPS PPS UTC PPS time is set time is not set have UTC info no UTC info time from GPS time from user
10		Seconds	UINT8	0-59	Seconds
11		Minutes	UINT8	0-59	Minutes
12		Hours	UINT8	0-23	Hours
13		Day of Month	UINT8	1-31	Day of Month
14		Month	UINT8	1-12	Month of Year
15-16		Year	UINT16		Four digits of Year (e.g. 1998)

Table 75: Report Packet 0x8F-AB

Report Packet 0x8F-AC: Supplemental Timing Packet

This broadcast packet provides supplemental timing information once per second. Information regarding position, unit status and health, and the operational state of the unit is provided. This packet cannot be requested. When enabled, this packet is transmitted once per second shortly after packet 8F-AB.

The position sent in packet 8F-AC depends on the Receiver Operating Mode and on self-survey activity. When a self-survey is in progress, the position sent is the running average of all of the position fixes collected so far. When the self-survey ends or whenever the receiver is using a time-only operating mode, then the position sent is the accurate position the receiver is using to perform time-only fixes. When the self-survey is disabled or otherwise inactive and the receiver is using a position fix operating mode, then the position sent is the position fix computed on the last second.

Data Fields

Receiver Mode: This field shows the fix mode that the GPS receiver is currently configured for. The Resolution T spends most of its time in the Overdetermined Clock mode where it uses all available satellites to perform the best time-only fix possible. See packet BB for a description of all available receiver modes.

Self-Survey Progress: When a self-survey procedure is in progress, this field shows the progress of the survey as a percentage of fixes collected so far. The self-survey will be complete when the self-survey progress reaches 100 percent.

Minor Alarms: This field is bitwise encoded with several minor alarm indicators. A minor alarm indicates a condition that the user should be alerted to, but does not indicate an immediate (or necessarily any) impairment of functionality. For each bit, a value of 0 means that the condition is not indicated. Bits not described below should be ignored.

- Bit 1: When 1, indicates that the antenna input connection is open. More precisely, this bit indicates that the antenna input is not drawing sufficient current. Normally, the Resolution T provides power to the antenna's LNA (Low Noise Amplifier) through the center conductor of the antenna cable. On-board circuitry senses this current draw, and if low, this condition will be indicated. However, when the antenna is powered elsewhere (e.g. when using a splitter) then an antenna open condition is expected and does not imply a fault nor does it impair the operation of the Resolution T.
- Bit 2: When 1, indicates that the antenna input is shorted. More precisely, this bit indicates that the

antenna input is drawing too much current. On-board protection circuitry prevents any damage to the Resolution T when its antenna input is shorted to ground. This condition tends to indicates a fault in either the antenna cable or the antenna itself.

- Bit 3: When 1, indicates that no satellites are yet usable. In order for a satellite to be usable, it must be tracked long enough to obtain ephemeris and health data.
- Bit 5: When 1, indicates that a self-survey procedure is in progress.
- Bit 6: When 1, indicates that there is no accurate position stored in FLASH ROM.
- Bit 7: When 1, indicates that the GPS system has alerted the Resolution T that a leap second transition is pending.
- Bit 8: When 1, indicates that the Resolution T is operating in one of its test modes.
- Bit 9: When 1, indicates that the accuracy of the position used for time only fixes is questionable. This alarm may indicate that the unit has been moved since the unit completed the last self-survey. If this alarm persists, resurvey the position of the unit.
- Bit 11: When 1, indicates that the Almanac is not current or complete.
- Bit 12: When 1, indicates that the PPS was not generated this second. This could mean that there wasn't enough usable satellites to generate an accurate PPS output. It could also mean that the unit is generating an Even Second output (see Packet 8E-4E and the unit did not output a PPS on the odd second.

GPS Decoding Status: This field indicates the decoding status of the GPS receiver.

Local Clock Bias: This field contains the bias of the local clock. Note that this data cannot be used to increase the accuracy of the PPS output.

Local Clock Bias Rate: This field contains the bias rate of the local clock. Note that this data cannot be used to increase the accuracy of the PPS output.

Temperature: This field shows the temperature (in Celsius) as reported by Resolution T's on-board temperature sensor.

Latitude: This field carries the latitude of the position being shown. The units are in radians and vary from -pi/2 to +pi/2. Negative values represent southern latitudes. Positive values represent northern latitudes.

Longitude: This field carries the longitude of the position being shown. The units are in radians and vary from -pi to +pi. Negative values represent western longitudes. Positive values represent eastern longitudes.
Altitude: This field carries the altitude of the position being shown. The units are in meters (WGS-84.)

PPS Quantization Error: This field carries the PPS quantization error in units of seconds.

Broadcast Control: Packe8E/8F-A5, Mask 0, Bit 2

Byte	Item	Type	Value	Description
0	Subcode	UINT8	0xAC	
1	Receiver Mode	UINT8	0 1 3 4 5 6 7	Automatic (2D/3D) Single Satellite (Time) Horizontal (2D) Full Position (3D) DGPR Reference Clock Hold (2D) Overdetermined Clock
2	Reserved	UINT8	0 1 2 3 4 5 6	Reserved
3	Self-Survey Progress	UINT 8		0-100%
4-7	Reserved	UINT 32	0	Reserved
8-9	Reserved	UINT16	0	Reserved
10-11	Minor Alarms	UINT16	bit field	Bit 0: not used Bit 1: Antenna open Bit 2: Antenna shorted Bit 3: Not tracking satellites Bit 4: not used Bit 5: Survey-in progress Bit 6: no stored position Bit 7: Leap second pending Bit 8: In test mode Bit 9: Position is questionable Bit 10: not used Bit 11: Almanac not complete Bit 12: PPS was generated
12	GPS Decoding Status	UINT8	0 1 3 8 9 0x0A 0x0B 0x0C 0x10	Doing fixes Don’t have GPS time PDOP is too high No usable sats Only 1 usable sat Only 2 usable sats Only 3 usable sats the chosen sat is unusable TRAIM rejected the fix
13	Reserved	UINT8	0	Reserved
14	Spare Status 1	UINT8	0	
15	Spare Status 2	UINT8	0	
16-19	Local clock bias	Single		ns

Byte	Item	Type	Value	Description
20-23	Local clock bias rate	Single		ppb
24-27	Reserved	UINT32		Reserved
28-31	Reserved	Single		Reserved
32-35	Temperature	Single		degrees C
36-43	Latitude	Double		radians
44-51	Longitude	Double		radians
52-59	Altitude	Double		meters
60-63	PPS Quantization Error	Single		seconds
64-67	Spare			Future expansion

Table 76: Report Packet 0x8F-AC

UNUSED OR MISCELLANOUS PACKETS

Report Packet 0x13 Unparsable Packet

This packet is sent in response to a received packet that was unparsable. A packet is unparsable if the packet ID is not recognized or if the length or content of the packet is not correct for the packet ID.

Report Packet 0x13 Data Format

Byte	Type	Item
0	UINT8	Packet ID of unparsable packet
1-N	UINT8	Packet data bytes of unparsable packet

LEGACY PACKETS (UNUSED)

The four packets below will be sent , for historical reasons, when the Automatic Output Packets are enabled with packet Ox8E-A5, but the same information contained in these packets is contained in packets Ox8E-AB and Ox8E-AC and these old packets should be ignored.

Report Packet Ox54 Bias and Bias Rate

Information contained in super packets 8F-AB or 8F-AC

Report Packet Ox46 Health of Receiver

Information contained in super packets 8F-AB or 8F-AC

Report Packet Ox41 GPS Time

Information contained in super packets 8F-AB or 8F-AC

Report Packet 0x4B Machine Code ID and Additional Status

Information contained in super packets 8F-AB or 8F-AC

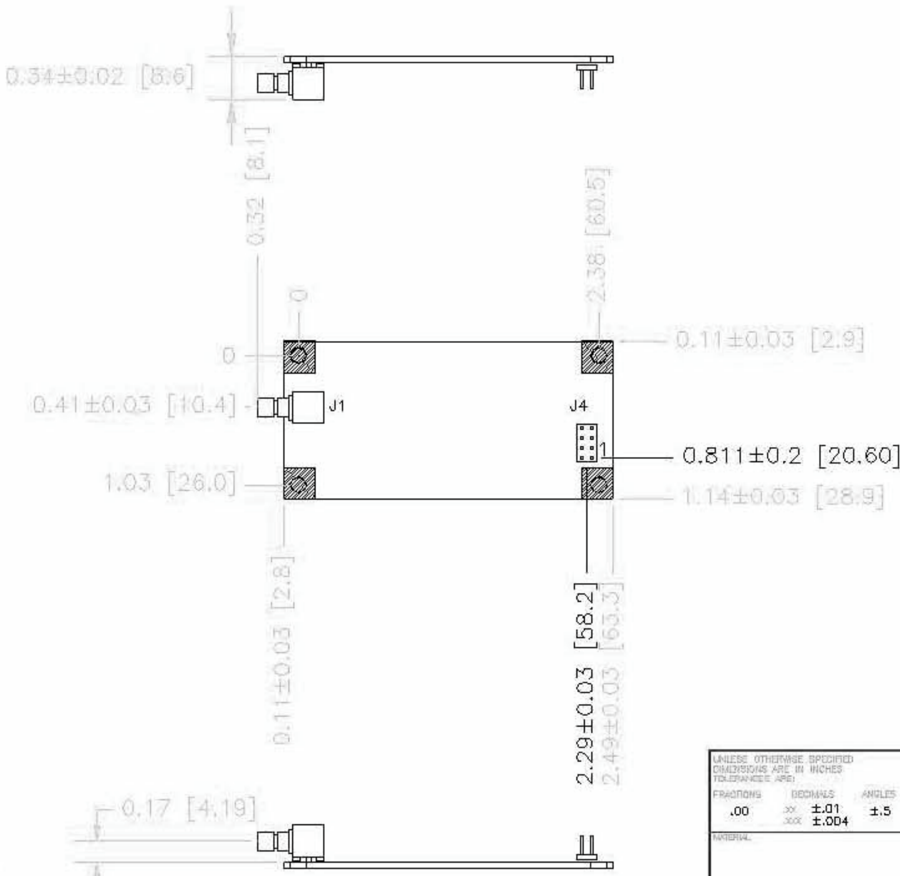
APPENDIX

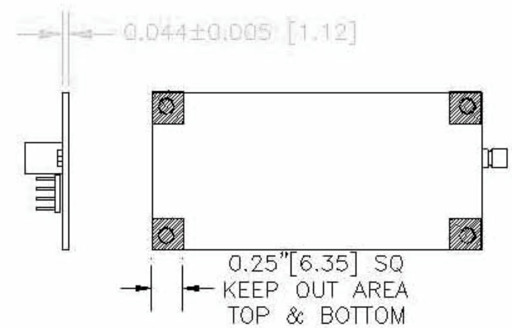
C

SPECIFICATIONS

The Resolution T is designed for a variety of embedded timing applications. This appendix includes the system specifications and mechanical drawings for the Resolution T and the available GPS antenna.

REVISIONS				
ECN	REV	DESCRIPTION	DATE	APPROVED
	A	ENGINEERING RELEASE	4/20/04	D.C.





NOTES:
1. RF CONNECTOR: SMB
   J4 8 PIN I/O CONNECTOR
   2X4 2mm
   Samtec TMM-104-01-T-D-SM

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
.00	.XX ±.01 .XXX ±.004	±.5

MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO.

CRITICAL DIMENSION for Internal Inspection only

APPROVALS		DATE
DRAWN	4/20/04	4/20/04
CHECKED		
ISSUED		

Trimble

MECHANICAL SPEC. - DSP

SIZE	FSCM NO.	DWG NO.	REV
B		52830-XX-MS	A
SCALE 2X		SHEET 1 OF 1	

FILE: 52830-XX-MS

DWG NO.	SHT.	REV.
52830-XX-MS		A

Bullet III GPS Antenna

Jam-Resistant Active GPS Antenna

ENVIRONMENTAL SPECIFICATIONS

Operating Temp:	–40° C to +85° C
Storage Temp:	–40° C to +100° C
Vibration:	10–200 Hz Log sweep 3g (Sweep time 30 minutes) 3 axes
Shock:	50 g vertical, 30 g all axes
Humidity:	Mil-STD-810E
Corrosion:	5% Salt spray
Waterproof:	Immersion to 1 meter

PHYSICAL CHARACTERISTICS

Dimensions:	3.05" D x 2.61" H (77.5 mm x 66.2 mm)
Weight:	6.0 oz (170 grams)
Enclosure:	Off-white plastic
Connector:	F-type or TNC
Mounting:	1"-14 thread or 3/4" pipe thread

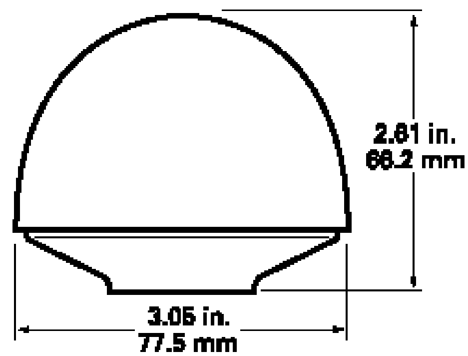
TECHNICAL/PERFORMANCE SPECIFICATIONS

Prime power:	+5 Volts DC (±10%)
Power consumption:	30 mA maximum
Output impedance:	50Ω
Frequency:	1575.42 MHz ± 1.023 MHz
Polarization:	Right-hand circular polarization (RHCP)
VSWR:	2.0 maximum
Axial ratio:	90°: 4.0 dB maximum; 10°: 6 dB maximum
Gain:	35 dB ± 3 dB
Noise:	3.3 dB maximum (25°C ±5°C)
Pass-band width:	50 MHz
Out of Band rejection:	f_o=1575.42 MHz f_o ±20 MHz: 7 dB min f_o ±30 MHz: 12 dB min f_o ±50 MHz: 20 dB min f_o ±100 MHz: 30 dB min
Azimuth coverage:	360° (omni-directional)
Elevation coverage:	0° to 90° elevation (hemispherical)

Specifications above also apply to be new 3.3Vdc Bullet III except as noted below:

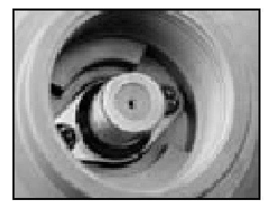
Gain:	30 dBi @ 25° c
Prime power:	3.3Vdc (±10%)
Power Consumption:	<20 mA
Connection:	TNC only
Recommended Cable:	• RG-6 with TNC to TNC connectors. 75ft maximum legnth • TNC-SMA adapter • 5.1" Adapter cable H.FL to SMA Bulkhead connector available for the Lassen PT or SQ

DIAGRAM



CONNECTORS


TNC


F-type

ORDERING INFORMATION

Accessories for 5Vdc version only

Rooftop Antenna Kit	Bullet III antenna with 75 feet of RG-59 cable, 8-inch type F to SMB adapter and instructions. For use in fixed site applications such as timing. Compatible with SVeeEight™, ACE GPS™ and Lassen™ modules.
Bullet III Cable Kit	50-foot (15 meter) RG-59 antenna cable with F connectors

Please visit our website for current information, part numbers, and ordering information at:
www.trimble.com/timing

All GPS receivers are subject to degradation of position and velocity accuracies under Department of Defense imposed Selective Availability (S/A)

Resolution T

Full-featured, low-cost, embedded GPS Timing Receiver

PERFORMANCE SPECIFICATIONS

General	L1 (1575.42 MHz) Frequency, C/A Code, 12-channel, parallel-tracking receiver, DSP-based	
Update Rate	TSIP @ 1 Hz; NMEA @ 1 HZ	
Accuracy	Horizontal Position:	<6 meters (50%), <9 meters (90%)
	Altitude Position:	<11 meters (50%), <18 meters (90%)
	Velocity:	0.06 m/sec
	PPS:	within 15 ns to GPS/UTC (1 Sigma)
		<5 ns with quantization error removed
Acquisition	Reacquisition:	<2 sec. (90%)
	Hot Start:	<14 sec (50%), <18 sec (90%)
	Warm Start:	<41 sec (50%), <45 sec (90%)
	Cold Start:	<46 sec (50%), <50 sec (90%)

Cold start requires no initialization. Warm start implies last position, time and almanac are saved by backup power. Hot start implies ephemeris also saved. Hot and Warm are shown for comparison purposes and are not used in timing applications.

Sensitivity	Acquisition	–136 dBm
	Tracking	–141 dBm
Operational (COCOM) Limits	Altitude	18,000 m
	Velocity	515 m/s

Either limit may be exceeded, but not both

PHYSICAL CHARACTERISTICS

Dimensions	66.3mm L x 32.1mm W x 8.5mm H (2.6"L x 1.3"W x 0.33"H)
Weight	approximately 12.5 grams (0.4 ounce)

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	–40° C to +85° C	
Storage Temperature	–55° C to +105° C	
Vibration	0.008 g^2/Hz	5 Hz to 20 Hz
	0.05 g^2/Hz	20 Hz to 100 Hz
	–3 dB/octave	100 Hz to 900 Hz
Operating Humidity	5% to 95% R.H. non-condensing, at +60° C	
Altitude	–400 to 18,000 m max	

ELECTRICAL SPECIFICATIONS

Prime Power	+3.3 VDC ±0.3 VDC
Power Consumption	GPS board only: 350 mW @ 3.3 V
Ripple Noise	Max 50 mV, peak to peak from 1 Hz to 1 MHz
Antenna Fault Protection	Short-circuit/open detection and protection

INTERFACE CHARACTERISTICS

Connectors	I/O:	8-pin (2x4) 2 mm Male Header
	RF:	Right-angle SMB (SMA optional)
Serial Port		1 serial port (transmit/receive)
PPS		3.3 V CMOS-compatible TTL-level pulse, once per second
		Rising edge of the pulse synchronized with GPS/UTC
Protocols		TSIP @ 9600 baud, 8 bits
		NMEA 0183 v3.0 @ 4800 baud, 8 bits
NMEA Messages		GGA, VTG, GLL, ZDA, GSA, GSV and RMC
		Messages selectable by TSIP command
		Selection stored in flash memory

ACCESSORIES

Rooftop Antenna	Bullet III, TNC (F) 3.3 VDC with 30 dBi gain.
	Bullet III, F 5 VDC with 35 dBi gain
Transition cable	SMB to F
Rooftop Antenna Kits	3 or 5 VDC

FOR MORE INFORMATION

E-mail us at: timing@trimble.com
Visit our website at http://www.trimble.com/restime

Specifications subject to change without notice.

Datums

Table A

Index	DX	DY	DZ	A-axis	Eccentricity	Description
0	**0**	**0**	**0**	**6378137.000**	**0.00669437999014**	**/*WGS-84*/**
1	-128	481	664	637797.155	0.00667437311265	/*Tokyo from old J6 values*/
2	-8	160	176	6378206.400	0.0067865799761	/*NAD-27*/
3	-9	151	185	6378206.400	0.00676865799761	/*Alaska/Canada*/
4	-87	-98	-121	6378388.000	0.00672267002233	/*European*/
5	-133	-48	148	6378160.000	0.00669454185459	/*Australian*/
6	0	0	4	6378135.000	0.00669431777827	/*WGS-72*/
7	0	0	0	6378137.000	0.00669438002290	/*NAD-83*/
8	0	0	0	6378137.000	0.00669437999014	/*NAD-02*/
9	0	0	0	6378137.000	0.00669437999014	/*Mexican*/
10	0	0	0	6378137.000	0.00669437999014	/*Hawaiian*/
11	0	0	0	6378137.000	0.00669437999014	/*Astronomic*/
12	0	0	0	6378137.000	0.00669437999014	/*U S Navy*/
13	-87	-98	-121	6378388.000	0.00672267002233	/*European*/
14	-134	-48	149	6378160.000	0.00669454185459	/*Australian 1984*/
15	-166	-15	204	6378249.145	0.00680351128285	/*Adindan-Mean*/
16	-165	-11	206	6378249.145	0.00680351128285	/*Adindan-Ethiopia*/
17	-123	-20	220	6378249.145	0.00680351128285	/*Adindan-Mali*/
18	-128	-18	224	6378249.145	0.00680351128285	/*Adindan-Senegal*/
19	-161	-14	205	6378249.145	0.00680351128285	/*Adindan-Sudan*/
20	-43	-163	45	6378245.000	0.00669342162297	/*Afgooye-Somalia*/
21	-150	-250	-1	6378388.000	0.00672267002233	/*Ain El Abd- Bahrain*/
22	-491	-22	435	6378160.000	0.00669454185459	/*Anna 1 Astr 1965*/
23	-143	-90	-294	6378249.145	0.00680351128285	/*Arc 1950-Mean*/
24	-138	-105	-289	6378249.145	0.00680351128285	/*Arc 1950- Botswana*/
25	-125	-108	-295	6378249.145	0.00680351128285	/*Arc 1950-Lesotho*/
26	-161	-73	-317	6378249.145	0.00680351128285	/*Arc 1950-Malawi*/
27	-134	-105	-295	6378249.145	0.00680351128285	/*Arc 1950- Swaziland*/
28	-169	-19	-278	6378249.145	0.00680351128285	/*Arc 1950-Zaire*/
29	-147	-74	-283	6378249.145	0.00680351128285	/*Arc 1950-Zambia*/
30	-142	-96	-293	6378249.145	0.00680351128285	/*Arc 1950- Zimbabwe*/
31	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960-Mean*/
32	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960-Kenya*/
33	-160	-6	-302	6378249.145	0.00680351128285	/*Arc 1960- Tanzania*/
34	-205	107	53	6378388.000	0.00672267002233	/*Ascension Isl 1958*/
35	145	75	272	6378388.000	0.00672267002233	/*Astro Beacon E 1945*/
36	114	-116	-333	6378388.000	0.00672267002233	/*Astro B4 Sorol Atoll*/
37	-320	550	-494	6378388.000	0.00672267002233	/*Astro Dos 71/4*/
38	124	-234	-25	6378388.000	0.00672267002233	/*Astro Station 1952*/
39	-133	-48	148	6378160.000	0.00669454185459	/*Australian Geo 1966*/
40	-127	-769	472	6378388.000	0.00672267002233	/*Bellevue (IGN)*/
41	-73	213	296	6378206.400	0.00676865799761	/*Bermuda 1957*/
42	307	304	-318	6378388.000	0.00672267002233	/*Bogota Observatory*/
43	-148	136	90	6378388.000	0.00672267002233	/*Compo Inchauspe*/
44	298	-304	-375	6378388.000	0.00672267002233	/*Canton Island 1966*/
45	-136	-108	-292	6378249.145	0.00680351128285	/*Cape*/
46	-2	151	181	6378206.400	0.00676865799761	/*Cape Canaveral mean*/
47	-263	6	431	6378249.145	0.00680351128285	/*Carthage*/

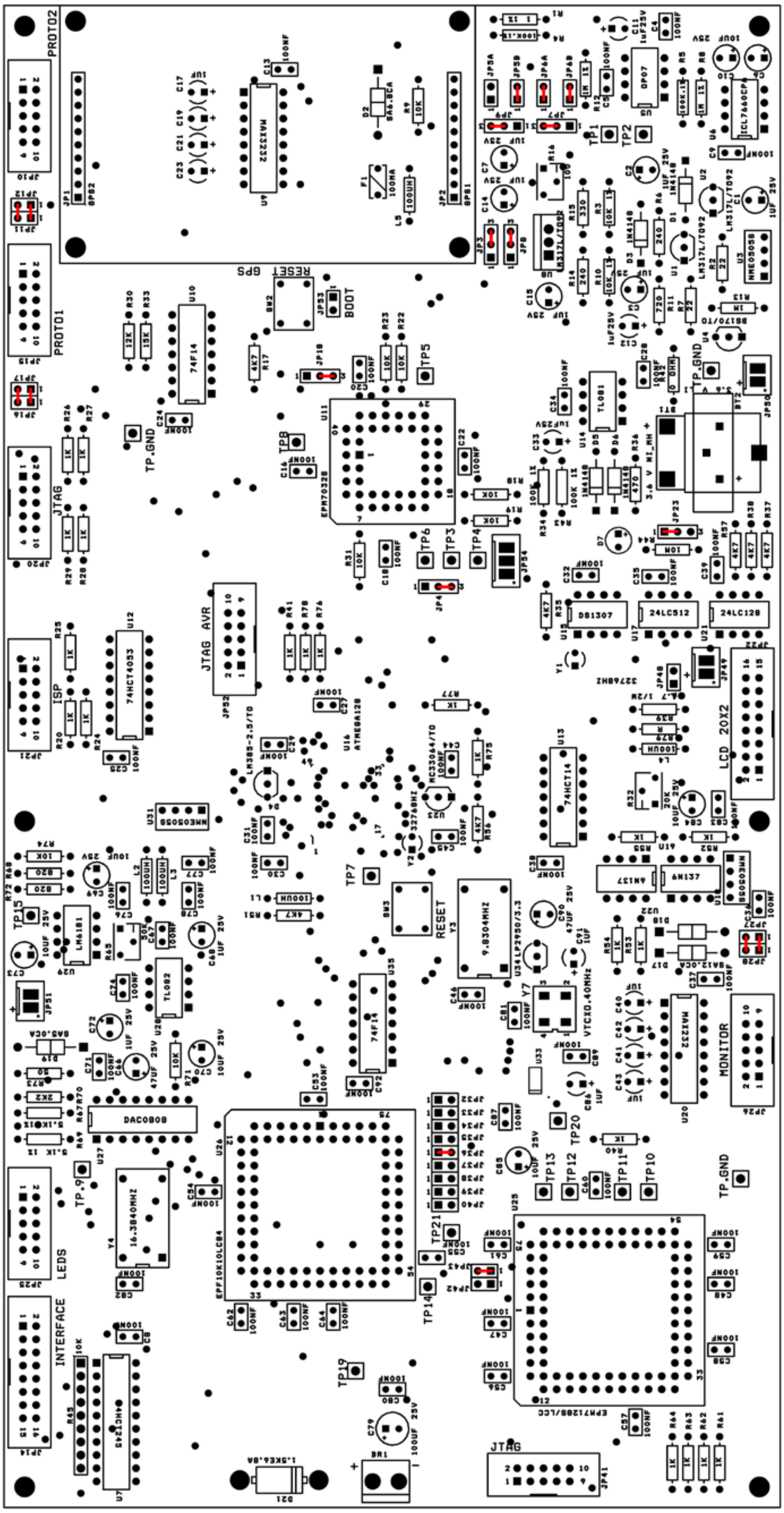
48	175	-38	113	6378388.000	0.00672267002233	/*Chatham 1971*/
49	-134	229	-29	6378388.000	0.00672267002233	/*Chua Astro*/
50	-206	172	-6	6378388.000	0.00672267002233	/*Corrego Alegre*/
51	-377	681	-50	6377397.155	0.00667437223180	/*Djakarta (Batavia)*/
52	230	-199	-752	6378388.000	0.00672267002233	/*DOS 1968*/
53	211	147	111	6378388.000	0.00672267002233	/*Easter Island 1967*/
54	-87	-98	-121	6378388.000	0.00672267002233	/*Euro 1950-Mean*/
55	-104	-101	-140	6378388.000	0.00672267002233	/*Euro 1950-Cyprus*/
56	-130	-117	-151	6378388.000	0.00672267002233	/*Euro 1950-Egypt*/
57	-86	-96	-120	6378388.000	0.00672267002233	/*Euro 1950-Eng/ Scot*/
58	-86	-96	-120	6378388.000	0.00672267002233	/*Euro 1950-Eng/Ire*/
59	-84	-95	-130	6378388.000	0.00672267002233	/*Euro 1950- Greece*/
60	-117	-132	-164	6378388.000	0.00672267002233	/*Euro 1950-Iran*/
61	-97	-103	-120	6378388.000	0.00672267002233	/*Euro 1950- Sardinia*/
62	-97	-88	-135	6378388.000	0.00672267002233	/*Euro 1950-Sicily*/
63	-87	-95	-120	6378388.000	0.00672267002233	/*Euro 1950- Norway*/
64	**-87**	**-107**	**-120**	**6378388.000**	**0.00672267002233**	**/*Euro 1950-Port/ Spain*/**
65	-86	-98	-119	6378388.000	0.00672267002233	/*European 1979*/
66	-133	-321	50	6378388.000	0.00672267002233	/*Gandajika Base*/
67	84	-22	209	6378388.000	0.00672267002233	/*Geodetic Datum 1949*/
68	-100	-248	259	6378206.400	0.00676865799761	/*Guam 1963*/
69	252	-209	-751	6378388.000	0.00672267002233	/*GUX 1 Astro*/
70	-73	46	-86	6378388.000	0.00672267002233	/*Hjorsey 1955*/
71	-156	-271	-189	6378388.000	0.00672267002233	/*Hong Kong 1963*/
72	209	818	290	6377276.345	0.00663784663020	/*Indian-Thai/Viet*/
73	295	736	257	6377301.243	0.00663784663020	/*Indian-India/Nepal*/
74	506	-122	611	6377340.189	0.00667053999999	/*Ireland 1965*/
75	208	-435	-229	6378388.000	0.00672267002233	/*ISTS O73 Astro 1969
76	89	-79	-202	6378388.000	0.00672267002233	/*Johnston Island 1961*/
77	-97	787	86	6377276.345	0.00663784663020	/*Kandawala*/
78	145	-187	103	6378388.000	0.00672267002233	/*Kerguelen Island*/
79	-11	851	5	6377304.063	0.00663784663020	/*Kertau 1948*/
80	94	-948	-1262	6378388.000	0.00672267002233	/*La Reunion*/
81	42	124	147	6378206.400	0.00676865799761	/*L.C. 5 Astro*/
82	-90	40	88	6378249.145	0.00680351128285	/*Liberia 1964*/
83	-133	-77	-51	6378206.400	0.00676865799761	/*Luzon-Phillippines*/
84	-133	-79	-72	6378206.400	0.00676865799761	/*Luzon-Mindanao*/
85	41	-220	-134	6378249.145	0.00680351128285	/*Mahe 1971*/
86	-289	-124	60	6378388.000	0.00672267002233	/*Marco Astro*/
87	639	405	60	6377397.155	0.00667437223180	/*Massawa*/
88	31	146	47	6378249.145	0.00680351128285	/*Merchich*/
89	912	-58	1227	6378388.000	0.00672267002233	/*Midway Astro 1961*/
90	-92	-93	122	6378249.145	0.00680351128285	/*Minna*/
91	-247	-148	369	6378249.145	0.00680351128285	/*Nahrwan-Masirah*/
92	-249	-156	381	6378249.145	0.00680351128285	/*Nahrwan-UAE*/
93	-243	-192	477	6378249.145	0.00680351128285	/*Nahrwan-Saudia*/
94	616	97	-251	6377483.865	0.00667437223180	/*Namibia*/
95	-10	375	165	6378388.000	0.00672267002233	/*Naparima*/
96	-8	159	175	6378206.400	0.00676865799761	/*NAD 27-Western US*/
97	-9	161	179	6378206.400	0.00676865799761	/*NAD 27-Eastern US*/
98	-5	135	172	6378206.400	0.00676865799761	/*NAD 27-Alaska*/
99	-4	154	178	6378206.400	0.00676865799761	/*NAD 27-Bahamas*/
100	1	140	165	6378206.400	0.00676865799761	/*NAD 27-San Salvador*/
101	-10	158	187	6378206.400	0.00676865799761	/*NAD 27-Canada*/

102	-7	162	188	6378206.400	0.00676865799761	/*NAD 27-Alberta/ BC*/
103	-22	160	190	6378206.400	0.00676865799761	/*NAD 27-East Canada*/
104	-9	157	184	6378206.400	0.00676865799761	/*NAD 27-Manitoba/ Ont*/
105	4	159	188	6378206.400	0.00676865799761	/*NAD 27-NW Ter/ Sask*/
106	-7	139	181	6378206.400	0.00676865799761	/*NAD 27-Yukon*/
107	0	125	201	6378206.400	0.00676865799761	/*NAD 27-Canal Zone*/
108	-3	143	183	6378206.400	0.00676865799761	/*NAD 27- Caribbean*/
109	0	125	194	6378206.400	0.00676865799761	/*NAD 27-Central Amer*/
110	-9	152	178	6378206.400	0.00676865799761	/*NAD 27-Cuba*/
111	11	114	195	6378206.400	0.00676865799761	/*NAD 27- Greenland*/
112	-12	130	190	6378206.400	0.00676865799761	/*NAD 27-Mexico*/
113	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Alaska*/
114	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Canada*/
115	0	0	0	6378137.0	0.00669438002290	/*NAD 83-CONUS*/
116	0	0	0	6378137.0	0.00669438002290	/*NAD 83-Mex/Cent Am*/
117	-425	-169	81	6378388.0	0.00672267002233	/*Observatorio 1966*/
118	-130	110	-13	6378200.0	0.00669342162297	/*Old Egyptian 1907*/
119	61	-285	-181	6378206.400	0.00676865799761	/*Old Hawaiian- mean*/
120	89	-279	-183	6378206.400	0.00676865799761	/*Old Hawaiian- Hawaii*/
121	45	-290	-172	6378206.400	0.00676865799761	/*Old Hawaiian*/
122	65	-290	-190	6378206.400	0.00676865799761	/*Old Hawaiian*/
123	58	-283	-182	6378206.400	0.00676865799761	/*Old Hawaiian*/
124	-346	-1	224	6378249.15	0.00680351128285	/*Oman*/
125	375	-111	431	6377563.4	0.00667053999999	/*Ord Sur Brit '36- Mean*/
126	375	-111	431	6377563.4	0.00667053999999	/*OSB-England*/
127	375	-111	431	6377563.4	0.00667053999999	/*OSB-Isle of Man*/
128	375	-111	431	6377563.4	0.00667053999999	/*OSB-Scotland/ Shetland*/
129	375	-111	431	6377563.4	0.00667053999999	/*OSB-Wales*/
130	-307	-92	127	6378388.0	0.00672267002233	/*Pico De Las Nieves*/
131	-185	165	42	6378388.0	0.00672267002233	/*Pitcairn Astro 1967*/
132	16	196	93	6378388.0	0.00672267002233	/*Prov So Chilean1963*/
133	-288	175	-376	6378388.0	0.00672267002233	/*Prov S. American 1956-Mean*/
134	-270	188	-388	6378388.0	0.00672267002233	/*Prov S. American 1956-Bolivia*/
135	-270	183	-390	6378388.0	0.00672267002233	/*Prov S. American 1956-N Chile*/
136	-305	243	-442	6378388.0	0.00672267002233	/*Prov S. American 1956-S Chile*/
137	-282	169	-371	6378388.0	0.00672267002233	/*Prov S. American 1956-Colom*/
138	-278	171	-367	6378388.0	0.00672267002233	/*Prov S. American 1956-Equador*/
139	-298	159	-369	6378388.0	0.00672267002233	/*Prov S. American 1956-Guyana*/
140	-279	175	-379	6378388.0	0.00672267002233	/*Prov S. American 1956-Peru*/
141	-295	173	-371	6378388.0	0.00672267002233	/*Prov S. American 1956-Venez*/
142	11	72	-101	6378206.4	0.00676865799761	/*Puerto Rico*/
143	-128	-283	22	6378388.0	0.00672267002233	/*Quatar National*/
144	164	138	-189	6378388.0	0.00672267002233	/*Qornoq*/
145	-225	-65	9	6378388.0	0.00672267002233	/*Rome 1940*/
146	-203	141	53	6378388.0	0.00672267002233	/*Santa Braz*/
147	170	42	84	6378388.0	0.00672267002233	/*Santo (DOS)*/
148	-355	21	72	6378388.0	0.00672267002233	/*Sapper Hill 1943*/
149	-57	1	-41	6378160.0	0.00669454185459	/*S. American 1969- Mean*/
150	-62	-1	-37	6378160.0	0.00669454185459	/*S. American 1969- Argentina*/
151	-61	2	-48	6378160.0	0.00669454185459	/*S. American 1969- Bolivia*/
152	-60	-2	-41	6378160.0	0.00669454185459	/*S. American 1969- Brazil*/
153	-75	-1	-44	6378160.0	0.00669454185459	/*S. American 1969- Chile*/
154	-44	6	-36	6378160.0	0.00669454185459	/*S. American 1969- Colombia*/
155	-48	3	-44	6378160.0	0.00669454185459	/*S. American 1969- Ecuador*/

156	-53	3	-47	6378160.0	0.00669454185459	/*S. American 1969- Guyana*/
157	-61	2	-33	6378160.0	0.00669454185459	/*S. American 1969- Paraguay*/
158	-58	0	-44	6378160.0	0.00669454185459	/*S. American 1969- Peru*/
159	-45	12	-33	6378160.0	0.00669454185459	/*S. American 1969- Trin/Tob*/
160	-45	8	-33	6378160.0	0.00669454185459	/*S. American 1969- Venezuela*/
161	7	-10	-26	6378155.0	0.00669342162297	/*South Asia*/
162	-499	-249	314	6378388.0	0.00672267002233	/*Southeast Base*/
163	-104	167	-38	6378388.0	0.00672267002233	/*Southwest Base*/
164	-689	691	-46	6377276.345	0.00663784663020	/*Timbalai 1948*/
165	-148	507	685	6377397.16	0.00667437223180	/*Tokyo-Mean*/
166	-146	507	687	6377397.16	0.00667437223180	/*Tokyo-Korea*/
167	-158	507	676	6377397.16	0.00667437223180	/*Tokyo-Okinawa*/
168	-632	438	-609	6378388.0	0.00672267002233	/*Tristan Astro 1968*/
169	51	391	-36	6378249.15	0.00680351128285	/*Viti Levu 1916*/
170	102	52	-38	6378270.0	0.00672267002233	/*Wake-Eniwetok*/
171	-265	120	-358	6378388.0	0.00672267002233	/*Zanderij*/
172	-384	664	-48	6377397.16	0.00667437223180	/*Bukit Rimpah*/
173	-104	-129	239	6378388.0	0.00672267002233	/*Camp Area Astro*/
174	-403	684	41	6377397.16	0.00667437223180	/*Gunung Segara*/
175	-333	-222	114	6378388.0	0.00672267002233	/*Herat North*/
176	-637	-549	-203	6378388.0	0.00672267002233	/*Hu-Tzu-Shan*/
177	-189	-242	-9	6378388.0	0.00672267002233	/*Tananarive Observ. 1925*/
178	-155	171	37	6378388.0	0.00672267002233	/*Yacare*/
179	-146.43	507.89	681.46	6377397.155	0.00667437223180	/*Tokyo GSI coords*/

Anexo III

Situación de componentes



JP4

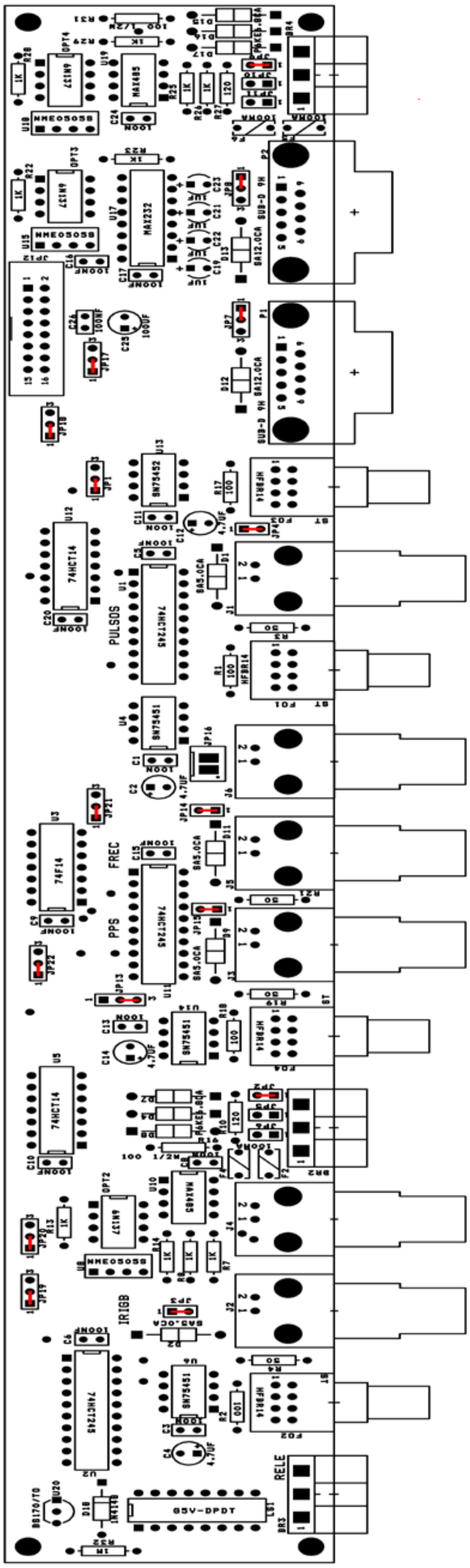
Posición 1-2 flanco de salida PPS low-high.

Posición 2-3 flanco de salida PPS high-low

Resto de puentes

Configuración de fábrica

PCB principal y JUMPER por defecto



JP2 y JP9

Puesto – Resistencia de bus 120 ohm.

JP7 y JP8

Posición 1-2, TX por pin 2
Posición 2-3, TX por pin 3

JP13

Posición 1-2, Salida por FO de 1 KHz
Posición 2-3, Salida por FO de PPS

Conectores RS485

A: Datos hilo A
B: Datos hilo B
T: Tierra

Conector RELE

A: Contacto normalmente abierto
C: Contacto normalmente cerrado
M: Común

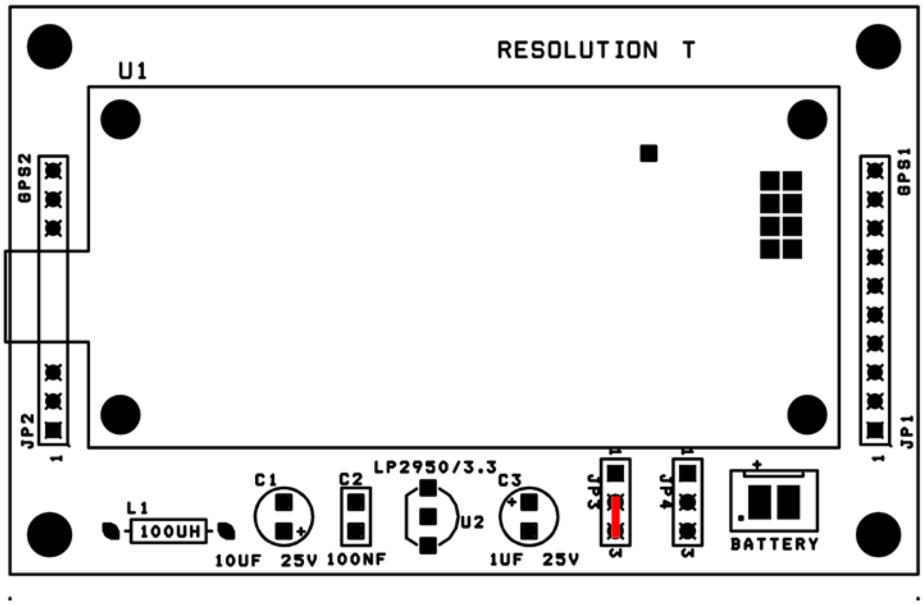
JP4 y JP14

Tranzorb a masa
Salida PP
Salida IRIGB00X.

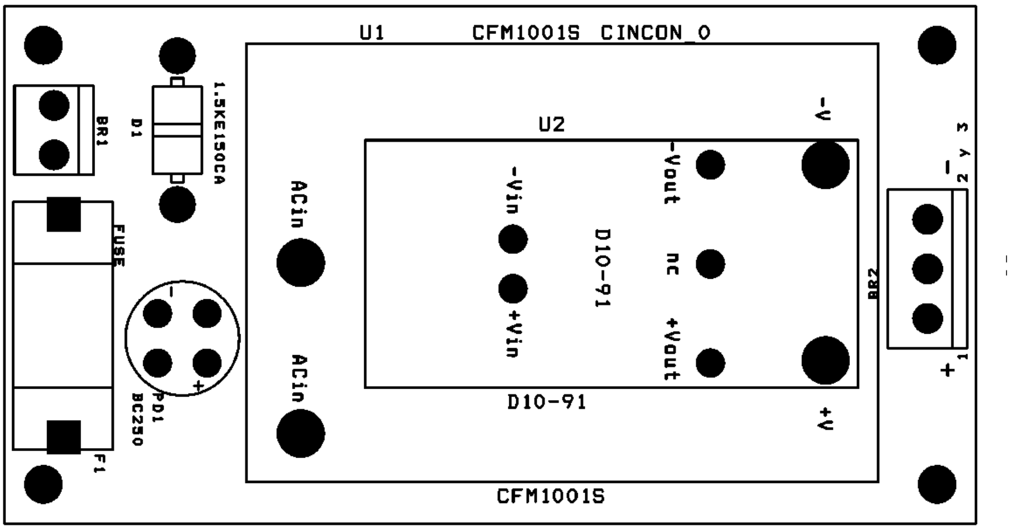
Resto de puentes

Configuración de fábrica

PCB Interface y JUMPER por defecto



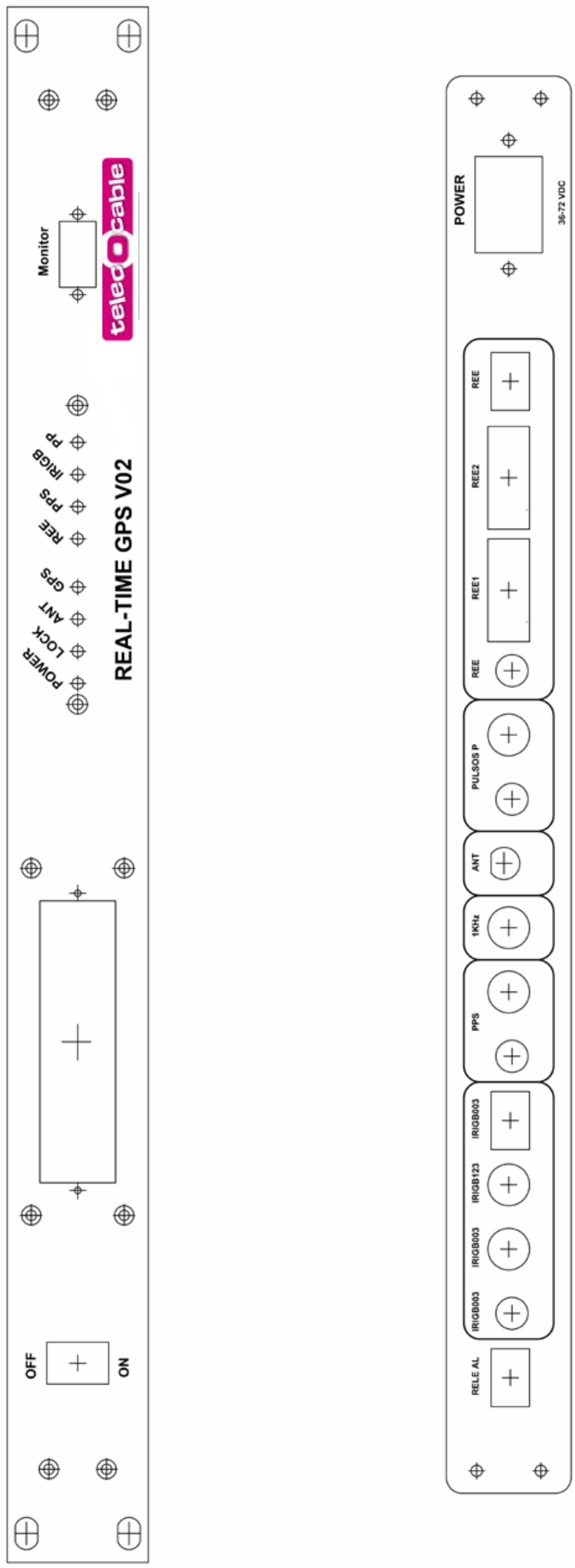
PCB Receptor GPS



PCB Fuente de alimentación

Anexo IV

Vista frontal. Vista Posterior


Monitor
PP
IRIGB
PPS
REE
GPS
ANT
LOCK
POWER
REAL-TIME GPS V02
OFF
ON
POWER
36-72 VDC
REE
REE2
REE1
REE
PULSOS P
ANT
1KHz
PPS
IRIGB003
IRIGB123
IRIGB003
IRIGB003
RELE AL


OFF
ON
POWER
LOCK
ANT
GPS
REE
PPS
IRIGB
PP
REAL-TIME GPS V02
Monitor


RELE AL
PPS
1KHz
ANT
PULSOS P
REE
REE1
REE2
REE
POWER