TS1 TimeSync Users Guide v1
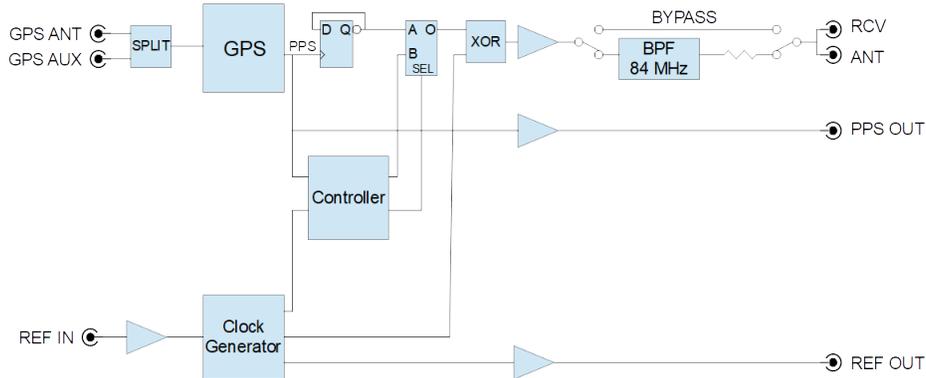## Board rev 1.1 (prototype), Firmware v1.8

The TS1 TimeSync unit generates a BPSK-modulated carrier signal that provides an extremely accurate time reference for SDR receivers used in TOF (Time of Flight) and TOA (Time of Arrival) measurements. The TS1 is also designed to generate BPSK-modulated over-the-air signals, timestamped to indicate TOT (Time of Transmission).

The TS1 is powered and configured via a USB-C connection. Configuration is via a virtual (USB) serial port command-line interface. Once configured, the TS1 does not require a computer connection and can be powered by a USB wall-wart. However, the computer connection may prove useful to monitor the TS1 status, and to provide the option for remote firmware updates.
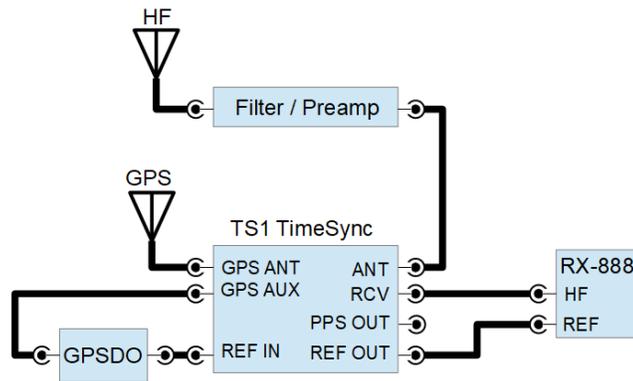
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Block Diagram

Typical TimeSync Injector Installation

Connections

GPS

The **GPS ANT** jack should be connected to either an active GPS antenna (the TS1 provides 3.3V power to the antenna), or to an active GPS antenna splitter. The **GPS ANT AUX** jack is connected to an internal passive splitter, which generally provides an adequate signal to a device such as a GPS Disciplined Oscillator (typically a Bodnar GPSDO).

Reference Clock

In most cases the TS1 **REF IN** jack should be connected to a reference clock, typically 10 or 27 MHz. The TS1 can be configured to use other reference frequencies between 5 and 30 MHz. If there is no reference clock, the TS1 will revert to an internal 10 MHz oscillator, but this does not have the accuracy or stability desired for most uses. The default external reference clock frequency is 27 MHz.

The **REF OUT** jack provides a clock that can be used as the reference clock for the SDR receiver. The default output frequency is 27 MHz (typically used for the RX-888 SDR), but the TS1 can be configured to provide virtually any other frequency on this port.

PPS Out

This jack provides a buffered version of the GPS PPS signal. This may be useful.

Note: The prototype rev 1.1 PC boards have this output inverted, so this a 100 ms *LOW* pulse.

RCV / ANT

These two ports are directly connected together, and when the TS1 is configured as a timesync injector they are driven by the TS1 modulated signal through a high-value isolation resistor. This resistance ensures that the received signal is not measurably attenuated, but an adequate level of timesync signal is still received.

A bypass path is provided via jumper selection that lets the TS1 be used as an over-the-air timestamp transmitter. This capability is currently under development.


Operation

Signal Path

Transmit Frequency

The transmit frequency is generated by the on-board Si5351 clock generator, referenced to either the internal 10 MHz clock or the external reference. This clock generator also provides the reference clock output, and an internal 20.46 MHz clock for the controller timer/counter which is used to generate optional modulation patterns.

Modulation

The modulating signal can come from two sources: The GPS PPS signal, or a modulating signal generated by the microcontroller. This is BPSK (Binary Phase Shift Keying) and is done using a digital XOR gate. The image below shows the BPSK modulation of a 7 MHz carrier.
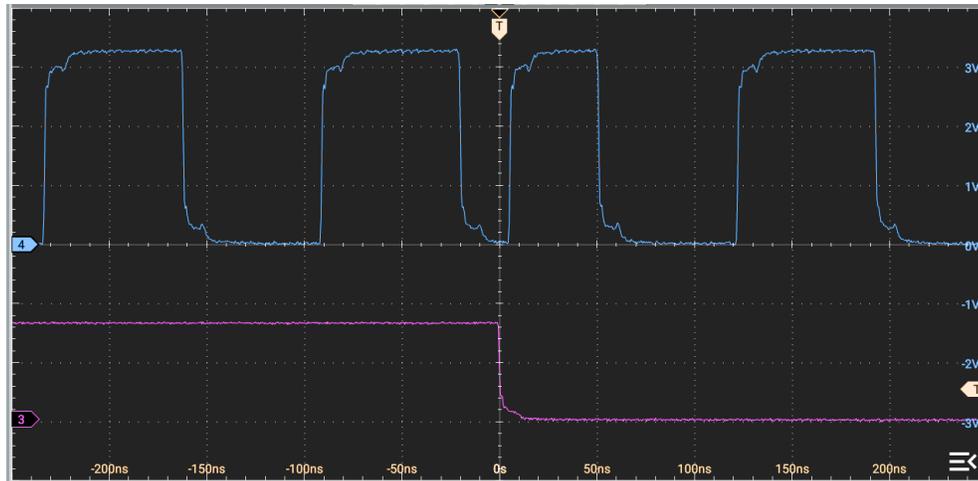
This modulation is unfiltered and so contains many sidebands. Passing this modulated signal through a low-pass or bandpass filter will reduce these sidebands somewhat, but unless this filter is impractically sharp, the sidebands will extend well beyond the audio spectrum. In the case of PPS modulation, this will be heard as one-second clicks. Below is the same 7 MHz BPSK modulated signal after being passed through a fairly wide bandpass filter (a Turn Island Systems Filter-Combiner).
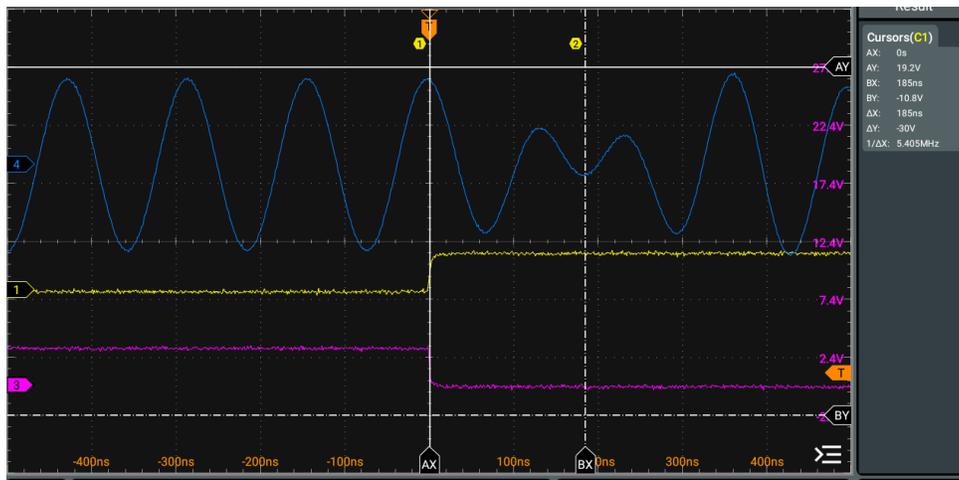
While this filter does a good job of reducing the square wave carrier harmonics, it does virtually nothing with the PPS-frequency sidebands. Below is the close-in spectrum of this signal:
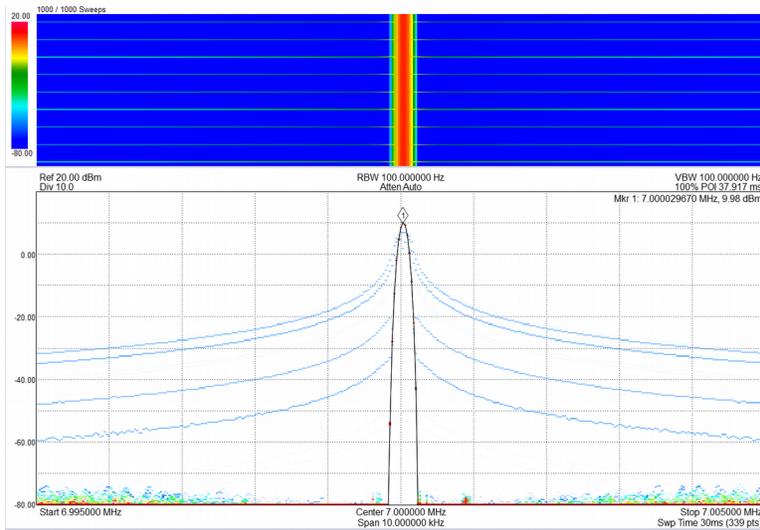
Below are the 7 MHz carrier and harmonics:
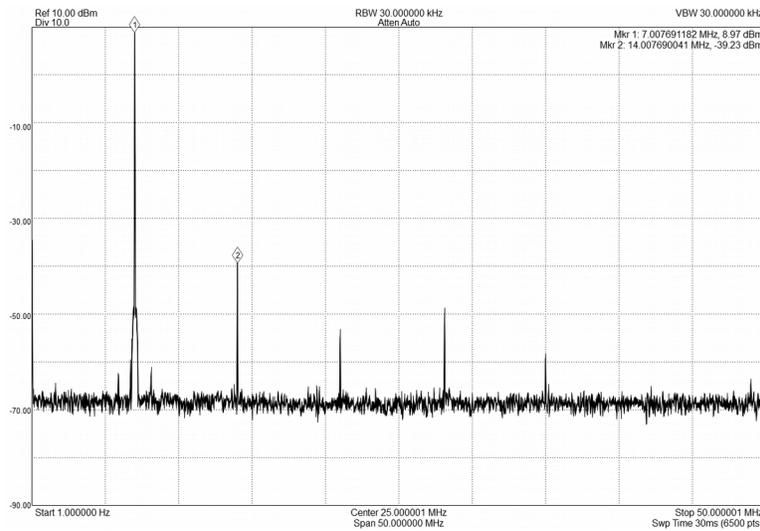
This isn't particularly important when the TS1 is used as a timesync injector, but when used to generate an over-the-air timestamped signal these factors should be kept in mind, particularly when higher bit-rate timestamp patterns are used. The current TS1 is a prototype, and the release version will very likely have some form of modulation shaping to reduce the sideband levels.

TimeSync Injector Mode

When jumpered for TimeSync injector mode, in the default configuration the TS1 generates a low-amplitude signal that is injected into the receive signal path. In this mode the injected signal is set to 84.225 MHz and passed through a 84 MHz bandpass filter and attenuator section, delivering a signal of approximately -33 dBm. This signal is additionally attenuated by the RX-888 60 MHz low-pass filter.

This 84.225 MHz frequency is aliased down by the SDR 129.6 MHz or 64.8 MHz sample rate, and was chosen to both minimize signal re-transmission through the antenna, and to place any aliased harmonic frequencies as far as possible from any "interesting" bands.

- Freq: 84.225 MHz
- Encroachment on "ham-interesting" bands: no closer than 0.475 MHz (including first five aliased harmonics)
- Alias (fSample 64.800 MHz) : 19.425 MHz
- Alias (fSample 129.600 MHz) : 45.375 MHz

Other output frequencies can be configured to suit other sample rates.

Time Stamp Transmitter Mode

When jumpered for use as a transmitter, the filter and attenuator are bypassed, the output signal is an unfiltered square wave, with an amplitude of about +10 dBm. The output frequency can be set to any frequency from 1 to 60 MHz. See the **TX**, **PLL**, and **OUT** commands for frequency-setting options.

Configuration
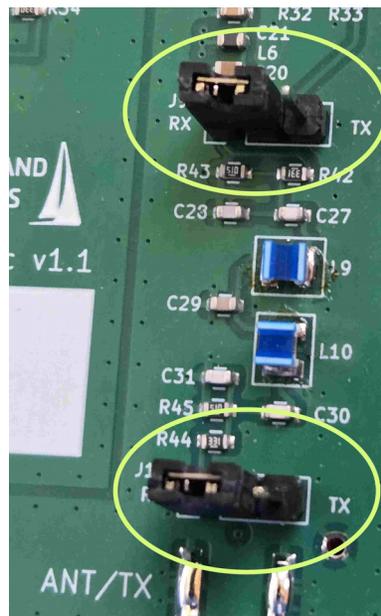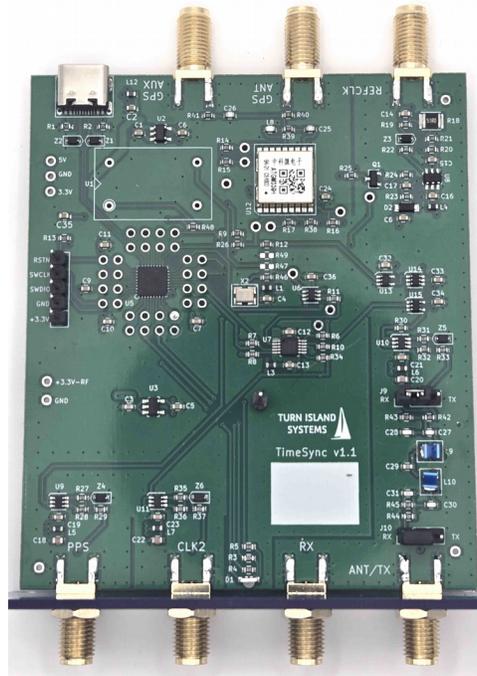
The jumpers shown above are in **timesync injection** mode (the R**X** position), where the output signal is sent attenuated and filtered to the **RCV** and **ANT** jacks.

For RX-888 timestamp transmit mode shift **both** jumpers to the right (to the T**X** position) to bypass the filter and attenuator. The TS1 is shipped with these jumpers as shown, in the timesync injection position

TS1 Status

The status of the TS1 is indicated by the front panel LED, and via the command-line "STATUS" command.

LED

- Initial power-on: a brief red, green, blue, white sequence

- Waiting for GPS acquisition: green blink

- BPSK modulation: green / blue as phase changes (green / off when no external clock)

- CW ID: blue = carrier on, green = carrier off

STATUS

Typing "status" (or "st" or "status", commands are not case-sensitive) shows this:

```
Mode: PPS
GPS lock, Satellites in view: 9
ref (external) : 27,000,000 Hz
pll[1][0]: 20 + 0 / 1 : 540,000,000.000000 Hz
pll[1][1]: 24 + 43 / 45 : 673,800,000.000000 Hz
out[0]: pll[0], 26 + 268 / 682, 1 : 20,460,000.000000 Hz
out[1]: pll[1], 8 + 0 / 1, 1 : 84,225,000.000000 Hz
out[2]: pll[0], 20 + 0 / 1, 1 : 27,000,000.000000 Hz
```

This is the default configuration, any changes made will be reflected in the STATUS command response.

Command Line Interface

```
TS>?
TimeSync v1.8, Board ID # 16a0cc84
MOD [0/1/2] : 0 = PPS modulation, 1 = PRBS modulation 2 = IRIG modulation
PLL [I/X] [0/1] [A] [B] [C] : Set PLL Dividers
OUT [channel (0/1/2)], [PLL(0/1)], [A], [B], [C], [D] : Set channel pll # and output dividers
REF [external reference frequency in Hz] : Set external reference frequency
TX [Freq in Hz] :
REFOUT [0/1] : 1 = reference output enabled
STAT : Show status, dividers and frequencies
NMEA [0 / 1 / 2]
MSG [id message]
ID [0-10] : ID every n minutes
WPM [CW speed in WPM]
RATE [1-120] : Data rate divider
DELAY [n] : add/subtract from 10us delay on modulation output
FILTER [0-3] : analog BPSK envelope filtering (0 = none)
ECHO [1/0] :  Echo on/off
REPORT [0-3] : Report level
READ : Read Config
SAVE : Save Config
DEFAULT : Restore default configuration
UPDATE YES : load new program
TS>23:06:00, PPS
```

As shipped, the TS1 is configured as a timesync injector, and if the external clock is 27 MHz no changes are necessary. The timesync signal injected into the receiver signal path is at

Other external reference clock frequencies will require setting of the Si5351 PLL and output divider registers.

For help on any command, enter "COMMAND_NAME ?"

MOD [0 / 1 / 2 / 3]

This enables different modulation (or mode) capabilities of the TS1. In the v1.8 firmware only MOD 0 (PPS BPSK) is supported. The other modes are under development.

REF [external reference frequency in Hz]

If your external reference frequency is something other than 27 MHz this command will allow the frequency display calculations to be correct. But this **will not** set the clock generator PLLs for you. You must do that with the PLL command.

This will be made automatic in a later release.

TX [frequency in Hz]

This command sets the output frequency to anything in the range from 1MHz to 60 MHz. The command format can be (for example) "TX 10100000" or "TX 10100K" or "TX 10.1M"

In firmware v1.8 the frequency setting is not as accurate as it might be – usually within 1 Hz but not at the higher frequencies. This will be improved in a later release. The reported frequency is exact to the accuracy of the reference clock.

Use the **OUT** command to set the dividers for exact control of the output frequency,

DEFAULT

DEFAULT restores the factory-default configuration

SAVE

The SAVE command makes the configuration changes permanent

UPDATE YES

To load new firmware, type "**UPDATE YES**". This will bring up a new folder window (or in a linux command-line interface create a new folder), typically called "TIS Boot". Copy the new program file – this will have a ".UF2" extension – to the folder. The TS1 should then automatically restart.

ID [0-10] : ID every n minutes

For timesync injection ID should be set to 0 (no ID). This is the default.

For over-the-air timestamp transmission allowable ID intervals are 1 to 10 minutes. An interval of "1" will send the ID message once every minute, with no timestamp signal being sent. An interval of "10" will send nine minutes of timestamp transmissions, followed by one minute for ID.

MSG [id message]

This is the ID message, to be sent on on/off-keyed Morse code. The default message is "TEST DE B0GUS". You obviously want to change this!

WPM [CW speed in WPM]

Enter the desired CW speed in WPM. The default is 18 WPM, and the allowable range is 8 – 30 WPM.

REPORT [0-3] : Report level

The default is level 1, which provides a once per minute display of the UTC time and the TS1 operating mode.

Level 0 is no report at all, levels > 1 are used for debugging and advanced program operation information

NMEA [0 / 1 / 2]

"NMEA 1" : displays the GPS serial NMEA "RMC" message

"NMEA 2" : displays all NMEA messages

"NMEA 0" : no messages shown. This is the default.

ECHO

This enables/disables a command-line echo.