BeeLine GPS User's Guide
V0.8
Aug 4, 2007

1 Introduction

The BeeLine GPS Telemetry transmitter integrates a microcontroller, an FM radio transmitter, a GPS module and an active GPS receiver antenna onto a single, small, low power board. An on-board microcontroller converts the latitude, longitude and altitude from the GPS module into an AX.25 data packet. This AX.25 data packet is then modulated and transmitted at 1200 baud over a radio link. A suitable receiver and packet decoder (TNC) are required on the receiving end. Software decoders such AGWPE and MIXW, as well as hardware decoders like the Byonics PicPac and the Kenwood TH-D7(a) are just a few examples of the supported hardware (all amateur radio TNC that supports the AX.25 standard should work).

2 Important Battery Information

The BeeLine Transmitter is designed to operate off of a single cell lithium polymer battery. Other battery sources may be used, but the MAXIMUM BATTERY VOLTAGE MUST BE LESS THAN 6.3 volts, otherwise **damage to the on-board processor may result.** By changing or removing components on the board, it is possible to use higher voltage levels (*up to 16Volts, 9.2 is OK, max determined by the voltage regulator. Actually, the Vreg can handle 16V, but then power dissipation becomes a problem. Maximum realistic input voltage without a heat sink is limited to 9V or so.*)

The battery has **not been charged**. They arrive partially charged from the factory and should have sufficient charge to operate for a limited time. Please fully charge the battery before extended use.

The supplied battery has a 750mah capacity and will last for at least 10 hours.

2.1   Lithium Battery Safety

They can't be beat for power density, but they must ONLY be charged with a charger specifically designed for Li-Poly batteries. It's also very important that they do NOT get discharged below approx 3 volts. You can read the battery voltage with the programming interface, but there are no provisions for automatically shutting down the unit should the voltage get too low (future enhancement).

A fully charged battery should allow for updates every 2 seconds for a period of 8 hours without over discharging the battery. If the unit is left powered on for an extended period of time, you WILL destroy the battery. You won't harm the Beeline, but you WILL need a new battery.

Undercharging, overcharging, or shorting the lithium polymer cell can cause electrolyte leakage, gassing, explosion and/or fire. If the battery begins to 'swell' or 'puff', discontinue use immediately. Do not attempt to charge or continue to use.

3 Programming Software

The BeeLine GPS programming software is available for download here: http://www.bigredbee.com/software.htm.

4 First Power On

The transmitter frequency is pre-set to 433.920 MHz and your call sign has been pre-programmed. The battery may not be fully charged, but should be good enough for preliminary testing. Please fully charge the battery before extended use! (it may take 10+ hours to fully charge an empty battery).

Attach the RF antenna if necessary, apply power, and place the unit with a CLEAR VIEW of the sky so the GPS receiver can acquire a lock on the necessary satellites. It may take up to 20 minutes for the GPS to initially lock. Subsequent lock times will occur much quicker. Prior to lock, the BeeLine will transmit valid packets containing 'random' location data. Once lock is obtained, the current position will be transmitted. The device will continue to transmit the last valid position received should it lose lock.

5   Data Formats

The packets transmitted from the BeeLine GPS come in one of two formats: APRS and TEXT. The Text version, if enabled, transmits the latitude and longitude with 4 decimal digits of accuracy. The APRS version only transmits 2 digits of accuracy due to the format of the APRS data packet. Altitude for both packet formats is transmitted in meters above sea level.

```
┣ TNC ▭
► 1: K7RKT-1
  N   45° 25.86'
  W 122° 44.12'
```

Above is an example of the Kenwood TH-D7 screen showing the latitude and longitude display of an APRS formatted packet. TEXT formatted packets can be decoded by other devices including the PicPac from Byonics.

6   Low Voltage Shutdown

Lithium polymer batteries can be severely damaged if the voltage goes below 3.0v. The A/D converter data can be used to shut down the processor and transmitter. Enabling this option will prevent the battery from being destroyed if the transmitter is accidentally left on for extended periods. While it is possible to disable this feature, it is not recommended. When the battery voltage goes below the specified threshold, the transmitter and GPS are powered off, and the processor enters a low power sleep state. Even though it is powered down, the processor still draws a small amount of current.

It is important to unplug the battery when not in use!

7   BeeLine GPS Communicator:

This WINDOWS ONLY application is used to modify the transmit characteristics stored in flash on the BeeLine GPS.

1) Remove all cables from the Beeline, and unplug the battery
2) Plug the serial adapter into your PC's serial port.
3) Start the windows application.
4) Apply power, and wait approximately 10 seconds
5) Connect the serial interface to the BeeLine GPS.
6) Click on "READ"

Note:
- It is recommended that you issue a read command before a write.
- The PC Serial port cable should be a simple "extension" cable, not a null-modem cable that swaps pins.
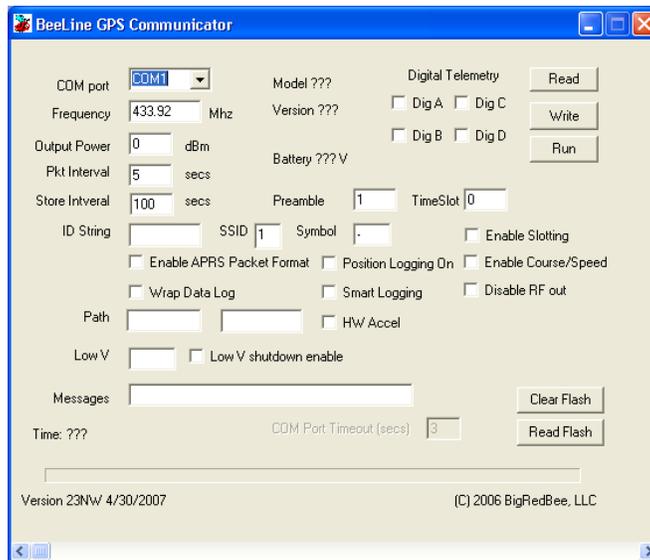
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Figure 1: BeeLine GPS Communicator

Figure 1 shows the BeeLine GPS Communicator. Each of the fields is described below.

- **Com port**: Set the proper serial port. If you need a com port # that is not available in the drop-down menu, simply type the desired value into the text box.
- **Frequency**: This is the RF carrier frequency the packet will be sent out on. Possible values are 420-450 Mhz
- **Output Power**: Set between -10 dBm and 12 dBm
- **Packet Interval**: Number of seconds between packet transmissions
- **Store Interval:** Number of seconds between writes to on-board memory
- **Preamble:** Number of IDLE bits sent before start of packet data
- **TimeSlot:** Number of seconds to delay if slotting is enabled.
- **ID String**: Your amateur radio callsign. Not more than 6 characters in length
- **SSID:** The SSID in the APRS packet. The default is 1, possible values are 1 thru 15
- **Symbol:** The symbol character in the APRS packet. The default is '-'
- **Enable APRS Packet format:** When this option is checked, APRS position packet will be transmitted
- **Position Logging On**: Position and altitude data will be logged into o-board memory.
- **Enable Slotting:** Turn Time Slotting ON. See below
- **Enable Course/Speed**: The coarse and speed are transmitted as part of the data packet
- **Disable RF Out**: Disables RF transmissions
- **Wrap Data Log**: When set, data is overwritten starting at the beginning after the end is reached.
- **Smart Logging**: See Below
- **Path**:   Each is 7 characters in length. If you're not familiar with AX-25 digipeating protocols, it's best to leave these values alone. Placing an 'X' in the first character of the first path will eliminate the path from the transmitted packet.
- **Low V Shutdown Enable**: Set this option if you whish the microcontroller to shut down the transmitter and GPS when the voltage gets below the value you set in "Low V".
- **Low V**: See above
- **Time:** Time (in seconds) since power has been applied. Certain internal events may cause the timer to be reset.
- **Read Data:** Data memory is read from the BeeLine GPS and stored to disk in the working directory in a file called beegps.kml. If the file exists, an error is displayed. The .kml file is an ascii file with headers and footers designed to be compatible with Google Earth.
- **Erase Data** Erases the on-board flash memory

8 Smart Data Logging

The Beeline GPS logs latitude, longitude and altitude data into an on-board serial eeprom. There are three options for storing data

1. Data logging stops when the memory is filled
2. Data logging continues indefinitely, wrapping to the beginning after writing to the last memory location
3. Smart Data Logging: A 'launch event' is detected, and data is stored until the memory is full. Several samples prior to the launch event are preserved.

Details of the Smart Data logging algorithm (state machine) follow:

Power On: When the BeeLine GPS is powered on, it enters the *base altitude* state.

Base Altitude: The BeeLine GPS begins looking for a base altitude from the GPS engine. When it detects 32 consecutive valid GPS position reports, each with four or more satellites in view, the BASE ALTITUDE is recorded, and the state transitions to *launch detect*. While in this state, the altitude is preceded with a '*' character.

Launch Detect: The BeeLine GPS begins looking for a launch condition. When 3 consecutive GPS positions reports, each with four or more satellites in view, that is 100 meters above the Base Altitude, the state transitions to *fill memory*. While in this state, the altitude is preceded with a '^' character.

Fill Memory: The BeeLine GPS records latitude, longitude and altitude data, wrapping when it reaches the end of memory, and continues writing up until the 32 samples before the sample where launch detect was stored. When memory is filled, the state transitions to *full*: While in this state the altitude is preceded with the 'V' character.

Full: No more samples are stored into memory. While in this state, the altitude is preceded with the 'F' character. Data packets are transmitted continually.

Helpful Hint: Once the unit has transition passed the Base Altitude state, take care to keep a GPS lock at all times. If lock is lost, the altitude may become unreliable, and a launch detect condition may be detected. The unit will continue to transmit coordinates normally, but may fill the record buffer before the actual launch has occurred.

8.1 Hardware Acceleration Switch

An optional hardware acceleration switch (G-switch) is available. Launch detect is signaled by the G-switch instead of attitude data from the GPS. To enable the hardware g-switch, check the appropriate box. Smart data recording must also be enabled. A launch condition is triggered when the G-switch sees 2.1g's for longer than 250 milliseconds. If the hardware G-switch option is enabled, then the digital telemetry bit 'C' can not be enabled. See section below.

9 Time Slotting

Time slotting allows multiple transmitters to share the same frequency.

If Time Slotting is enabled, the transmitters will synchronize their transmit times to the GPS clock.

If the first unit is set to transmit every ten seconds, and its timeslot is set to 0, it will transmit at 0 10, 20, 30, 40, and 50 seconds past the top of the minute.

If a second unit is also set to transmit every 10 seconds, but has its timeslot value set to 3, it will transmit at 3, 13, 23, 33, 43, and 53 seconds past the top of the minute.

10 Digital Telemetry

The BeeLine GPS supports up to 4 bits of digital telemetry.   Each can be independently enabled. Digital telemetry and course/speed are not compatible; they can not be enabled at the same time.

```
┣ TNC ▭            ┣ TNC ▭
► 1: K7RKT-1      ► 1: K7RKT-1
   A1B1C1/-A=         /-A=00122
   00122
```

Above is an example of the Kenwood TH-D7 screen with telemetry bits A, B, and C enabled. The GPS is not locked, and the altitude is 122 meters. All of the input bits are pulled high.   To the right is the display with the digital telemetry bits disabled.

10.1 Digital Telemetry Inputs

By default, all digital inputs will be read as a logical "1" if no connection is made. Each bit is pulled up via an on-board pull-up resistor. To signal a logical '0', the input must be connected to Ground, or driven low by external logic. A current limiting resistor is recommended to protect the input of the microcontroller when driven by external logic.
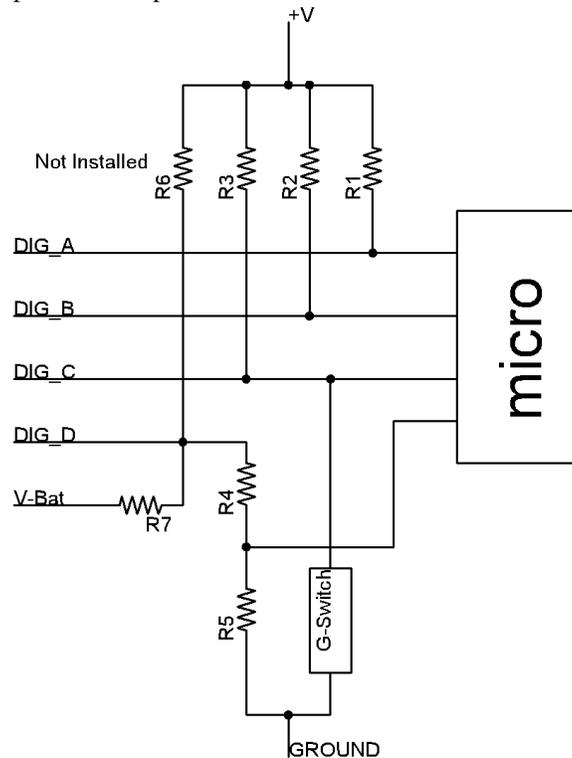

Figure 2: Digital Telemetry Inputs

Data Bit A and B: Data bit A is a dedicated input.   It is pulled high via an onboard 10K ohm pullup resistor. In the default state, it will be read as a '1'. If this wire is connected to ground, it will be read as a '0'.

Data bit C is shared with the hardware G-switch. If the hardware G-switch is not installed (or not enabled via software), this input will behave the same as data bits A and B. The G-switch is a normally open switch that will connect this digital input to ground when closed. It is not possible to enable both the HW G-switch smart beaconing feature and data bit C at the same time. However, since the G-switch is a normally open switch, it will not interfere with another switch added in parallel.

11 Battery Charger

The battery charger has two alligator clips that need to be connected to the battery in order to charge it. Take two pieces of solid core wire, and strip ¼" off each end. Insert one end into the battery connector, and clip the alligator to the end of the other. See section 10 for the battery connector pinout.

The charger has two buttons: a 'test' button and a 'polarity' button. The button that 'clicks' when pushed is the polarity button.

1) Connect the battery to the charger. DO NOT PLUG INTO THE WALL.
2) Push the test button, the green light will glow.
3) If the light doesn't come on, push the polarity button, and repeat step 2.
4) Plug into the wall. The light will blink until the battery is charged.

12 Firmware upgrade

The firmware upgrade utility is a Windows Console application. Open a command window (Start->Run->cmd), and make sure that the flash utility (beeflash.exe) and the appropriate .hex file are in the same directory.

The command line is:
C:> beeflash.exe <comm port> <hexfile> [-v]

For example:
C:> beeflash.exe com1 gspfsk.hex

1) Remove all power connectors and cables
2) Connect the serial interface to the PC
3) Plug the serial interface into the BeeLine GPS
4) Invoke the flash upgrade utility
5) Follow the on-screen directions.

Here is a screen capture of a firmware upgrade progressing normally:

Figure 3: BeeFlash firmware upgrade

The verify option will perform a verify ONLY operation. No firmware modification will occur.

For example:
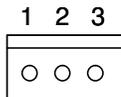C:> beeflash.exe com1 gspfsk.hex –ver

13 GPS Firmware upgrade

It may be necessary to upgrade or modify the firmware settings of the GPS module itself. Please see http://www.bigredbee.com/docs/BLGPS/configurator.zip for instructions on performing this update.

14 Connectors
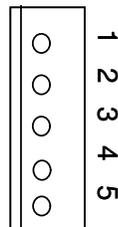
14.1 Battery Connection

(looking down from above)

Pin 1: Battery -
Pin 2: Battery +
Pin 3: N/C


14.2 ICSP / Serial Connector

(looking down from above)

Pin 1: TTL level transmit data out (ICSP_DCLK)
Pin 2: TTL level receive data in   (ICSP_DATA)

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Pin 3: Ground
Pin 4: 3.3V (output of voltage regulator)
Pin 5: MCLR

14.3 Digital Telemetry Connector

Pin 1: DIG_C   (Yellow)
Pin 2: GND   (Black)
Pin 3: DIG_D   (Green)
Pin 4:
Pin 5: DIG_B   (Orange)
Pin 6: DIG_A   (Red)

```
  ┌─────┐
  │  ○  │ 1
  │  ○  │ 2
  │  ○  │ 3
  │  ○  │ 4
  │  ○  │ 5
  │  ○  │ 6
  └─────┘
```
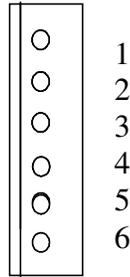
15 GPS Module Limitations

The GPS Receiver firmware contains an algorithm that allows either the speed limit (515 m/s) or altitude limit (18,000 m) to be exceeded, but not both. This allows the receiver to be used, for example, in high altitude (research balloon) applications.

Power consumption of the GPS module (excluding antenna) is 27mA at 3.3 V (89 mw).

16 FAQ

How do I decode these packets?
In addition to a suitable radio receiver, you will need an APRS packet decoder. You can use your PC and soundcard with standard APRS software, or a dedicated decoder like the PicPac (http://www.byonics.com/picpac) from Byonics. Kenwood makes the TH-D7 with an integrated packet decoder.

I already have a BeeLine Transmitter, can I upgrade?
No, they are completely different boards. But, the serial adapter and battery charger (and Yagi antenna) are compatible.

What's the range?
It has been tested to more than **20 miles** (line of site). Range on the ground is much less, and very dependant upon terrain.

How big it it?
The board measures 2 7/8" x 1 1/4", the antenna is 6.25" long. It fits inside a 38mm body tube.

How long does the battery last?
The integrated Lithium-Poly battery will power both the GPS AND the transmitter for at least 8 hours. With some creative power management (like turning the GPS off after the rocket has landed) the transmitter should be capable of transmitting for at least a week. (TBD)

Does it store any data from the flight?
Yes, with the optional memory upgrade, the GPS data log from the flight is recorded for download to your PC at a later date!

My Kenwood has an integrated TNC, can I use that?
ABSOLUTELY!

I see ??-*callsign* display on my Kenwood, what does that mean?

The Kenwood TH-D7 will display ??-*callsign* (ie, ?? K7RKT-1) when it receives valid packet that contains random data in lat/lon fields. As soon as the GPS locks, valid data will be displayed

I see dp-*callsign* display on my Kenwood, what does that mean?
The Kenwood TH-D7 will display *dp-callsign* (ie, dp K7RKT-1) when it decodes a duplicate packet.

I see 'my location' displayed on the Kenwood TH-D7, what does that mean?
The Kenwood will display 'my location' of the callsign and ssid are the same as that of the BeeLine: The solution is simply to change the callsign/ssid of one or the other.

Which other TNC's work?
We have tested the following TNC's:
Hardware: Byonics PicPac, AEA PK-88, PacComm TNC-220, Kenwood TH-D7
Software: AGWPE (WinAprs), MIXW

17 Packet Format

	APRS	No APRS	
0	to	to	**1**
7	from	from	**8**
14	relay1	relay1	**15**
21	relay2	relay2	**22**
28	Ctrl	Ctrl	**29**
29	Protocol	Protocol	**30**
30	Packet Type	Packet Type	**31**
31	latitude	latitude	**32**
39	seperator		**40**
40	longitude		**41**
41		seperator	**42**
42		longitude	**43**
48			**49**
49	seperator 2		**50**
50	msg		**51**
53		msg	**54**
54	altitude	altitude	**55**
58			**59**

Figure 4: APRS Data Packet Format

18 Board Layout

RF Output

Serial / Programming connector pin 1
2
3
4
5

3: Secondary Serial Port
2
1

GPS Module

Power Connector

Figure 5: Board Diagram