EME Beacon 144MHz Driver Source

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This unit was designed as a driver for the DL0SHF 10GHz EME Beacon Project, but the controller forms the basis of a new generation beacon source for MFSK modes in general. he complete unit consists of several modules:

The controller, based around a 16F628 PIC also includes an-board GPS receiver for timing.

The Frequency source, which here is an LMX2541 Fractional-N Synthesizer Chip. Full details of the synthesiser module can be found at [1]

An amplifier / driver capable of delivering up to 300mW
Optional 10MHz crystal oscillator for non-critical standalone operation (not a TCXO as labelled on the diagram)
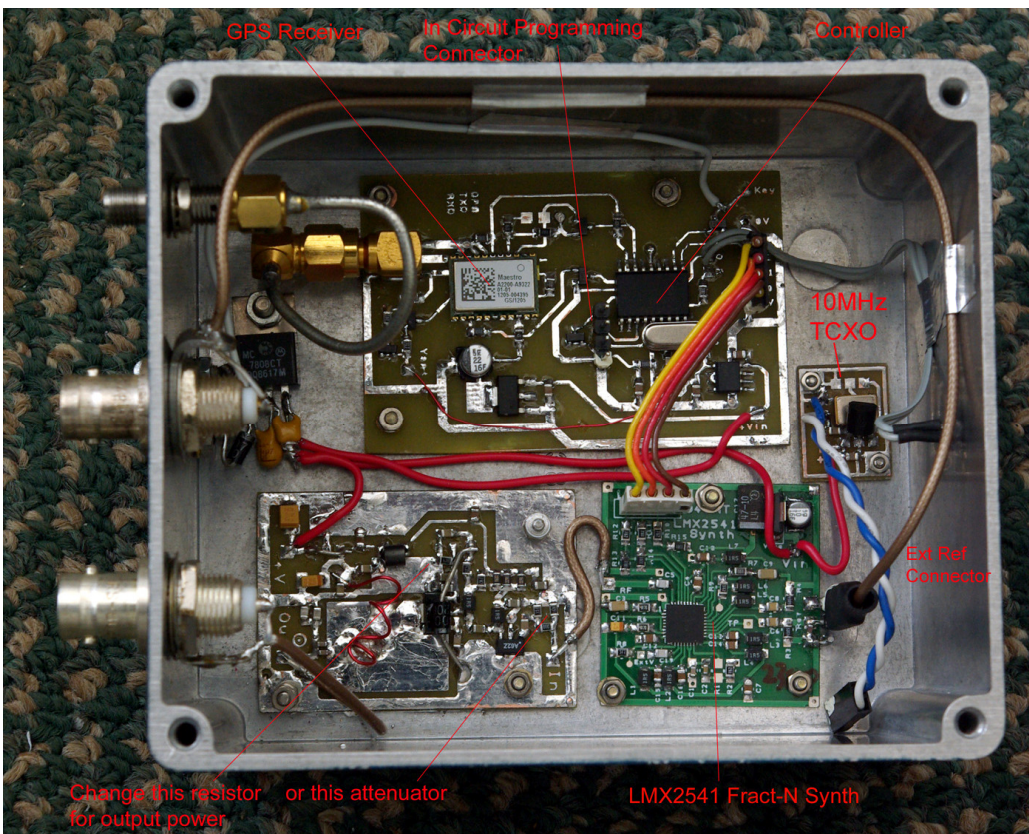
The modules making up the complete beacon source.

A screening plate, not shown, normally sits over the PA

Connectors and Interface

External connections are provided on the rear face as follows:

Feedthrough pin for power supply input. This can be in the range +11 to 16V DC. A higher input voltage is permissible if external temperature is not excessive. An internal voltage regulator drops this to 8V and there is a series reverse polarity protection diode. Current consumption is approximately 340mA

Feedthrough pin for Keying / Transmitter control. On the unit supplied this is intended to control a transmitter and is active for the Tx sequence, then off to allow a rest / cooling period. A 2N7002 switched to ground is the active state; standby is open circuit. Switching capability is 100mA at up to 40V. There is no overcurrent protection or current limiting.

An SMA connector for the GPS antenna. This includes a current limited 5V supply for active antennas. GPS antenna power is supplied through the thin red jumper lead on the controller board. If a passive GPS antenna or one that has a separate power supply is connected, remove this jumper.

BNC Connector for RF Output. Output level has been set at 180mW, but can be adjusted by either changing the value of the emitter resistor of the output transistor or by changing the values of the attenuator resistors on the input to the amplifier module.

BNC Connector for 10MHz reference input. To use this, the coaxial cable has to be connected to the synthesizer reference input via the two pin header after removing the connector for the internal oscillator. See the photograph for connections. External reference input level is not critical, and a value in the range −3 to +10dBm is acceptable.

A bicolour Yellow / Green LED on the front panel shows operating status.

Controller Operation

The controller unit includes a Maestro / SiRF single chip GPS receiver that delivers NMEA timing data to the PIC. Only the GPRMC sentence is used.

The firmware generates messages in the WSJT / JT4 format and also in CW using Frequency Shift Keying. The messages are formed in real time from a combination of the fixed callsign stored in EE memory and variable data, consisting of a hashed timestamp to allow verification of reception reports. Full details of the timestamp hash can be found at [2].

Every minute, the controller reads date and time from the GPS, merges this with the individual key, also stored in EE , then calculates the timestamp for that interval. The same information type is also transmitted in CW. Commands are sent via a four-wire ICP interface to the LMX2541 Fract-N synthesiser to generate the JT4G tones. The transmit sequence is as follows:

On the start of the even minute, the LMX2541registers are set to generate frequencies at the wanted output, with a Fract-N frequency grid set for JT4G of 315 / 16 = 19.6875Hz. The Tx control line is enabled (grounded). The pre-calculated JT4 symbols (values from 0 – 3) are multiplied by 16 and used as an offset to the fractional part of the frequency generated by the synthesiser. Each value is sent to the chip in sequence at a rate of 4.375Hz until the complete JT4 symbol set has been sent. This occurs after approximately 48 seconds. When the JT4 sequence completes, the Tx Control is released, allowing about 10 seconds of additional cooling period.

The grid spacing for JT4G does not allow an exact carrier frequency to be generated (only multiples of 19.69Hz are possible) so once the JT4 transmission is completed, the Fract-N grid is then reprogrammed for 10Hz spacing so the exact designated carrier frequency can be generated. The act of reprogramming the LMX2541 registers for a different grid may cause a brief glitch in output, so this is done during the time the Tx disabled

At the odd minute:00 point, the Tx line is reenabled and transmission continues with the callsign and timestamp associated with this odd minute, sent twice in CW with a two second gap with the carrier at the

mark frequency between the two.   After the second CW transmission, this is followed by a one second period of carrier at the mark frequency.   Depending on the length of the CW data, this will now be at approximately odd minute :30 seconds.   The Tx control is then released, allowing approximately 30 seconds for the transmitter to "rest" or cool before the sequence repeats.   The synthesiser is generating at the carrier frequency during this period.

Front Panel LED Indicator

This flashes to show different situations:

When the controller is first turned on, it gives short yellow flashes to show the GPS data is invalid. The flashing is slightly irregular, once or twice per second, and corresponds to NMEA data packets coming from the GPS receiver.   While the GPS is locking, the Tx line is NOT enabled.

When the GPS has locked up, this changes to Green flashes with slightly irregular short off periods, and the Tx line is immediately enabled.   Plain carrier is generated until the first minute:00 interval where normal operation starts, depending on whether this is an odd or even minute.

During the even minute, while transmitting JT4 data, the LED flashes yellow at half-symbol rate, around 2.2Hz.   When the JT4 transmissions ceases, it changes to flashing green.

At the odd minute, the LED flashes yellow corresponding to the CW data currently being transmitted. During the two second gaps, it shows green.

During the 8 seconds and 30 second gaps in standby operation,   green flashing resumes, indicating the GPS NMEA data is being read.   If GPS data becomes invalid due to loss of signal or jamming, the green flashes changes to short yellow flashes until the GPS has re-acquired the signal

Exact Frequencies   (as supplied for *DL0SHF* beacon)

Assuming accurate 10MHz reference input

Carrier and CW mark	144.025MHz (adjustable in 10Hz steps by reprogramming the PIC)
CW Space	144.0246MHz (400Hz low on key up)
JT4G Lowest Tone 0	144.024995MHz (4.725Hz below carrier)
JT4G tone spacing	315.00032Hz (= 10MHz / 31726)

Timestamp Key

A typical hexadecimal 64 bit key for the timestamp generation is 'CC74E4DE8A7D6F0E '
and will appear as 8 individual bytes : 0xCC, 0x74, 0xE4, 0xDE, 0x8A, 0x7D, 0x6F, 0x0E

If using the G4JNT *TimeCodeHash.exe* generation software (or the DOS / Command Prompt equivalent) included in *BCTMSTMP.ZIP* Ref [2],   this key can be entered either directly as the 16 hex characters string or by typing the pass phrase ' testhash '   into the respective text box. (*Make sure there are no extraneous spaces and all eight letters are in lower case.   Ensure it gives the hex key shown*)

Example JT4 Messages

These JT4 messages were decoded from actual test transmissions (using a different key)

```
113400  9  -11  0.8  -39   7 *      DL0SHF  34GAG
113600 10  -10  0.8  -39   7 *      DL0SHF  36MOR
113800 10  -10  0.7  -39   7 *      DL0SHF  38GIH
114000 10  -10  0.8  -42   7 *      DL0SHF  40JYR
```

Entering each hour minute combination into *TimeCodeHash.exe* after priming with the correct pass phrase (or hex key) and this date will generate the three letter code shown at the end of each message.

PIC In Circuit Programming

To change any parameters in the firmware or the message data it is necessary to reprogram the PIC controller. A four way header is provided for this purpose for direct connection to a PIC programmer such as the PicKit 2 or 3 using normal high-voltage programming and configuerd for in circuit programming. A custom lead will need to be made up to connect the Data, Clock, PGM and Ground leads from the controller board to their equivalents on the PIC programmer.

Connections on the 4-way header are, in sequence:

1	(Marked)	Ground
2		Data (PDG)
3		Clock (PGC)
4		Programme Voltage (PGM)

Debug Serial Interface

The In-Circuit Programming interface serves also as a debugging port during normal operation. The PGC connection on pin 3 of the four way ICP header delivers 8 bit serial RS232 ASCII data at 19200 baud showing intermediate results from the timestamp and JT4 calculations. See the controller circuit diagram for connections

Polarity is such that direct connection to a PC COM port running suitable terminal software will display the data.

The format for the debug data is similar to that shown in the table.

'Packed data' is the compressed message, encoded using the WSJT 37 character alphabet.

'Symbols' are the 206 JT4 two-bit values, packed four per byte.

Hooks in the firmware allow other intermediate values to be sent when enabled.

```
G8IMR/P 58MYN*

Packed  60 27 7F FF 10 ED 24 9D 43

Symbols
0A D2 9C DA 44 A8 AF 0A
20 8A 6F B4 67 76 C8 E9
25 F6 2C E8 F5 34 38 B6
44 CE 57 EE E7 11 3D A6
D9 FE 2B CF 83 59 71 50
40 D1 61 09 5D E9 48 9E
A4 51 F6 EC
..........

G8IMR/P 59BIT*

G8IMR/P 59BIT*
..................................

G8IMR/P 00ZYT*

Packed  60 27 7F FF 10 EB 70 F6 DD

Symbols
02 D2 94 D0 CC 28 2F 00
20 8A E7 B4 E7 FE C8 63
A5 76 24 E8 F5 B4 B0 B4
CC C6 5F 6E 67 93 35 26
D1 FE AB 4D 8B D9 F9 D0
40 D9 E9 09 D5 61 40 1C
AC D9 FE 64
..........
```
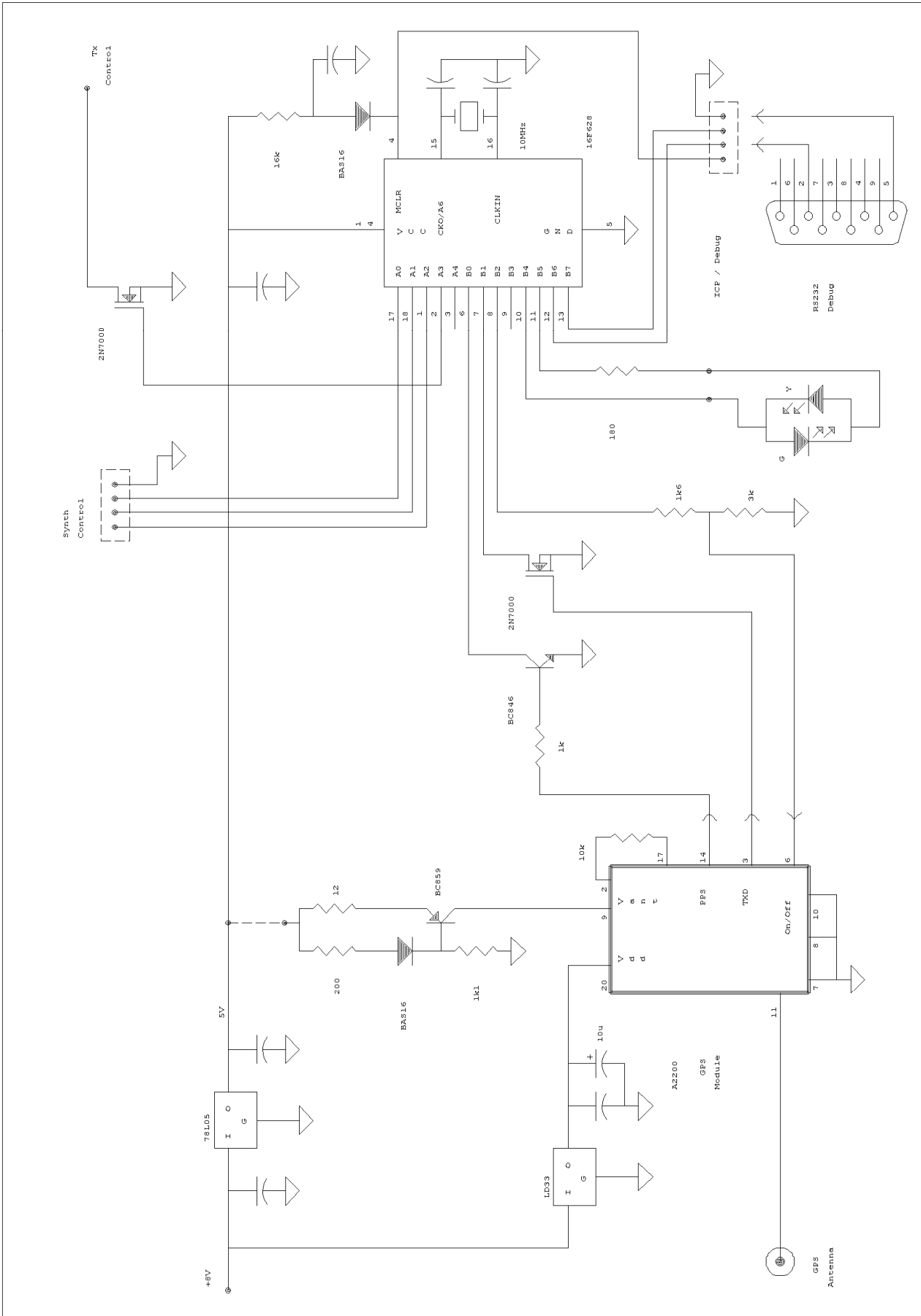
References

[1]   LMX2541 Fract-N Synthesiser   http://www.g4jnt.com/LMX2541_Synth_Module.pdf

[2]   Timestamp Hash   http://www.g4jnt.com/BeaconTimestamp.pdf
        Supporting Software   http://www.g4jnt.com/BCTMSTMP.ZIP

Figure 1 - Controller

Figure 2 - Module Interconnection and Driver amplifier

144MHz Beacon Source

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Since building the original Mark 1 driver at the end of 2013, users have requested that a few changes be made to the modulation format. The hardware for the driver remains the same, but the PIC code has been changed to add the following features :

The WSJT modulation has been changed from JT4G to JT4F, with its reduced tone spacing of 157.5Hz The message itself no longer has the time stamp hash incorporated and does not vary from one transmission to the next. This allows averaging to be used at the receive end for enhanced weak signal performance.

The message has been changed to one that *Deep Search*, incorporated in the later version of WSJT-X, can pick-up and use.   This gives an even weaker signal lower S/N capability at the receiver.

The JT4F message now sends the WSJT 'standard' message :   "**CQ DL0SHF JO54**"
The CW part of the message remains unchanged in content, sending the callsign followed by the minutes and the three letter timestamp hash sent twice.   For example   "**DL0SHF 13HID DL0SHF 13HID**" (at 13 minutes past the hour with a timestamp hash 'HID').   The key for the hash generator (and its generator passphrase) are unchanged.

A five second period of plain carrier, at the CW mark frequency has been added to the end of the CW message to assist listeners with narrow band measurements.   To compensate for heating during the extra transmission period, an off period of about 11 seconds, with the key line de-activated, has been introduced immediately after the JT4F finishes and before the odd minute where the CW starts.

Frequencies and Accuracy

For various reasons to do with the vagaries of the LMX2541 Fractional-N synthesizer programming, it is difficult to hit exact frequencies for all situations, so errors of a few Hz can occur which have been placed in non-critical places.   The carrier frequency is, however, correct and the JT4F tone spacings are within a fraction of a Hz of multiples of   157.5Hz.

Assuming an 'exact' 10MHz reference input and upconversion to 10GHz, the carrier frequency and CW mark is spot-on at 10368.025000MHz.   The CW space or key up is 395.4Hz below this at 10368.0246046MHz

The JT4F Tone Zero reference (lowest) frequency is 10368.0249937MHz   or 6.3Hz lower than the carrier.   In practice, users are unlikely to spot the difference unless specifically looking for it.

Transmission Sequence

The complete sequence is now :
     Even minute: 00 seconds
     Transmit Enable keys up at the Tone 0 frequency, then at 01 seconds the JT4F transmission
     starts
     At around :48 seconds the JT4F finished and the Tx Enable line is dropped
     At odd minute :00 seconds the CW starts sending its callsign followed by two digits
     corresponding to the minutes of the time and three letters, consonant-vowel-consonant,
     forming the timestamp hash.
     The CW repeats, so the whole message is sent twice.
     After the second CW transmission finishes, there is period of carrier for 5 seconds.
     Tx Keyline drops at approximately odd minute :30 seconds depending on the length of the
     hash code.
     The sequence then repeats at the even minute :00s

The approximately 11 seconds of Tx off between the end of the JT4F and the start of the CW has been added to compensate for the increased dissipation caused by the period of plain carrier after the CW message. Hopefully the two spread out off periods will allow slightly better cooling that the previous sequence offered.

Overview

The Mark 3 Beacon source comprises a completely new set of hardware and is not PIC firmware compatible with the Mark1/2 hardware. However, RF output is similar, 144.025MHz at an adjustable power level up to 300mW.   There is a ground-to-Tx enable output, and also additional loop around connections for an external control to enable power to the driver stage (+8V supply switching in / out)
Modulation type can be selected by a 5V logic level between QRA64-D and JT4-F.   Both modes send the identical message   "**CQ DL0SHF JO54**"

The CW part of the message remains unchanged in content from the Mark 1 / 2 version , sending the callsign followed by the minutes and the three letter timestamp hash sent twice.   For example   "**DL0SHF 13HID DL0SHF 13HID**"   (at 13 minutes past the hour with a timestamp hash 'HID').   The key for the hash generator (and its generator passphrase) are unchanged.

A five second period of plain carrier, at the CW mark frequency, allows for narrow band measurements. To compensate for heating during the transmission period, an off period of about 11 seconds, with the key line de-activated, lies immediately after the WSJT transmission finishes and before the odd minute where the CW starts.

The pulse-per-second signal from the GPS is used for timing, and a tighter timing specification is now in place.   If the GPS receiver has been fully updated, local copy of the WSJT modulation should result in a DT of close to zero.   The GPS module delivers correct timing on its NMEA output after a delay of up to 12 minutes after switch on, needed to acquire the leap-second offset.   So initial transmissions after a cold start could be up to 2 seconds early.

A preset pot inside, accessible though the PA shielding , adjusts output power.

Transmission Sequence

The complete sequence is now :

> Even minute: 00 seconds
> Transmit Enable keys up at the Tone 0 frequency, then at 01 seconds the WSJT
>   transmission starts
> At around :48 seconds the WSJT mode finishes and the Tx Enable line is dropped
> At odd minute :00 seconds Tx Enable is raised and the CW starts sending its
>   callsign followed by two digits corresponding to the minutes of the time and
>   three letters, consonant-vowel-consonant forming the timestamp hash.

> The CW repeats, so the whole message is sent twice.

> After the second CW transmission finishes, there is period of carrier for 5 seconds.

> Tx Enable drops at approximately odd minute :30 seconds depending on the
>   length of the hash code.   The Red LED then flashes with '**Q**' if QRA64-D
>   mode is selected, or '**J**' for JT4-F

> The sequence then repeats at the even minute :00s

Logic Level Mode Selection
A feed-through on the module allows the choice of one of two WSJT modes to be selected.   If set to +5V, logic '1' or left open circuit, QRA64-D mode is transmitted.   If set to logic '0' or connected to ground, JT4-F mode is transmitted.

Other Connections

The internal PA for up to 300mW of RF is enabled by linking the +8V out and +8V in feed throughs.
TX Enable switches to Ground when active.