General Purpose Beacon Driver Source

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This unit was originally designed as a driver for the DL0SHF EME Beacon Project, generating 144MHz for subsequent upconversion to 10GHz, but the controller forms the basis of a new generation beacon source for MFSK modes in general. The complete unit consists of several modules:

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

The Frequency source, an LMX2541 Fractional-N Synthesizer Chip. Full details of the synthesiser module can be found at [1]   It can generate frequencies up to 4GHz with a very fine frequency resolution / grid

An amplifier / driver capable of delivering up to 300mW for use in the V/UHF range.

Optional 10MHz crystal oscillator for non-critical standalone operation.
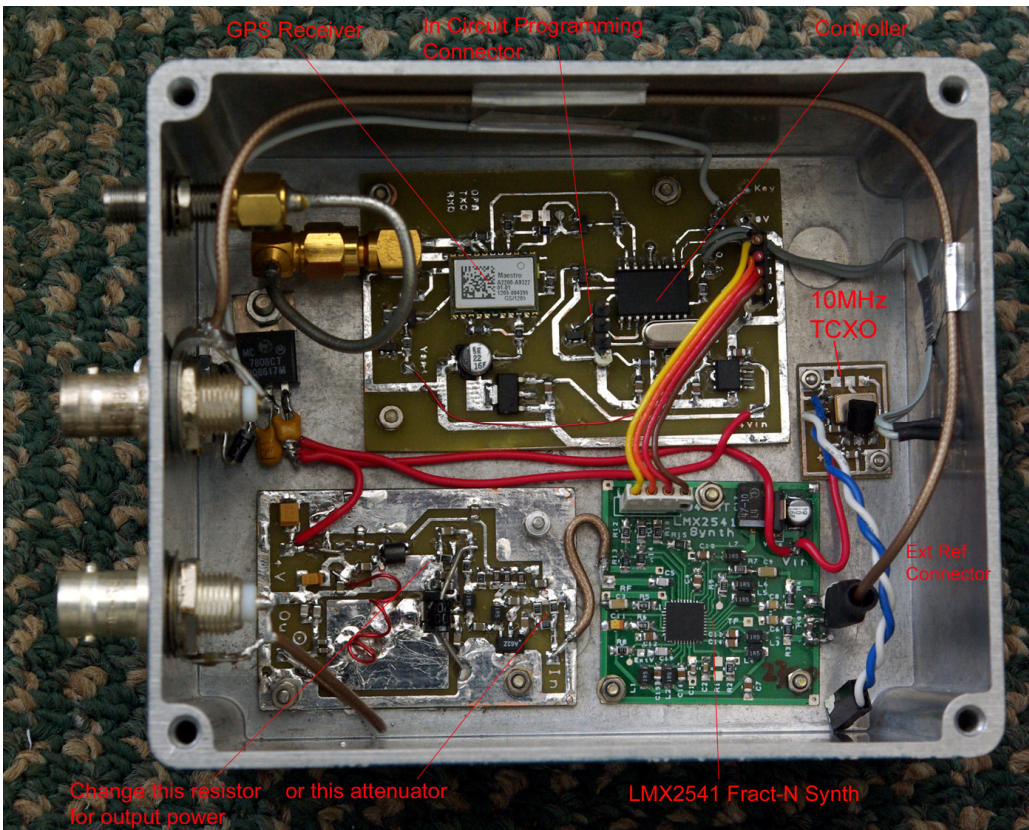
The modules making up the complete beacon source supplied to the DL0SHF project

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

Connectors and Interface

External connections are provided as follows:

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

Keying / Transmitter control. On the unit supplied for DL0SHF 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. Alternatively, the connection can be configured for ON / OFF pulse mode keying.

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.

RF Output. Output level has been set at 180mW on DL0SHF, 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.

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.

This version of the beacon source has no driver amplifier and generates frequencies from 40 to 432MHz, and also in the 1296MHz band. Alternative variants of the LMX2541 chip allow operation to 4GHz.
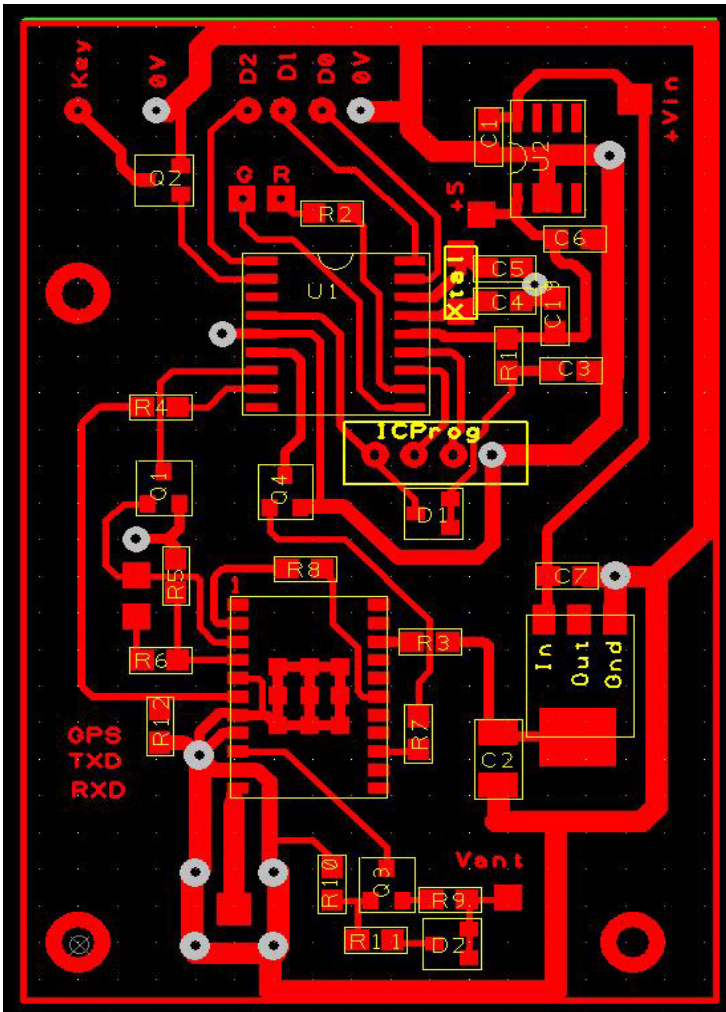
The PIC In-circuit programming header has been bought to a connector accessible via a slot cut in the lid of the box. This allows reprogramming of frequency / mode without having to remove the lid. The large unit top right is a high stability 10MHz TCXO

Controller Operation

The controller unit includes a Maestro / SiRF A2200-A single chip GPS receiver that delivers NMEA timing data to the PIC. Only the GPRMC sentence is used. The GPS module is available from RS Components Stock Number 765-8968

PIC firmware is specific to each data mode or beacon operation desired but the following is common to all versions. It can generate messages in most of the WSJT modes [2] and also in CW using either Frequency Shift Keying or on/off via the external interface. The messages are formed in real time from a combination of the fixed data stored in EE memory and for some modes, variable data. A version using the hashed timestamp [3] to allow verification of reception reports was supplied for the DL0SHF EME beacon

The controller reads timing information from the GPS NMEA stream and uses this to synchronise the WSJT message and optionally, in the case of time stamped messages, form part of the message data. Serial SPI data is sent via a four-wire ICP interface to the LMX2541 Fract-N synthesiser to generate the individual tones.

When sending WSJT modes, the grid spacing of the fractional-N synthesiser is set to the tone spacing (or a binary multiple or submultiple) of the mode in use. The grid spacing for the WSJT modes does not usually allow an exact carrier frequency to be generated, so once the WSJT transmission is completed, the Fract-N grid is then reprogrammed for a spacing such that 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. The Tx control is therefore inhibited for a short period during the reprogramming to avoid transmitting this glitch.

PIC Controller PCB. There is a continuous groundplane on the underside

Front Panel LED Indicator

This is used in most cases to indicate the status of the controller or the message state. A typical operation is that 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.

When the GPS has locked up, this changes to Green flashes with slightly irregular short off periods

Once the GPS is locked, normal timed operation starts at the minute:00 interval

During the even minute, while transmitting WSJT data, the LED flashes yellow at half-symbol rate, around 2.2Hz.   When the 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.

In the final 30 seconds of 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

However, as it is under software control, the LED can be programmed to show anything.

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 configured 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 can also serve also as a debugging port during normal operation. For complex firmware like the Timestamped message keyer or real time JT4 generation, The PGC connection on pin 3 of the four way ICP header can deliver 8 bit serial RS232 ASCII data showing intermediate results from the timestamp and JT4 calculations. Hooks in the firmware allow other intermediate values to be sent when enabled.

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.
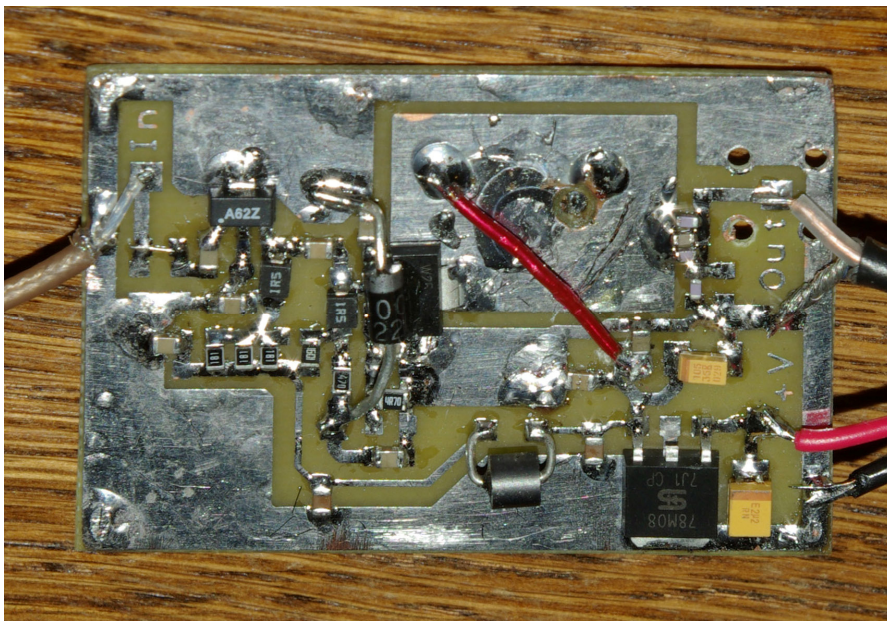
Figure 1 - Controller circuit diagram

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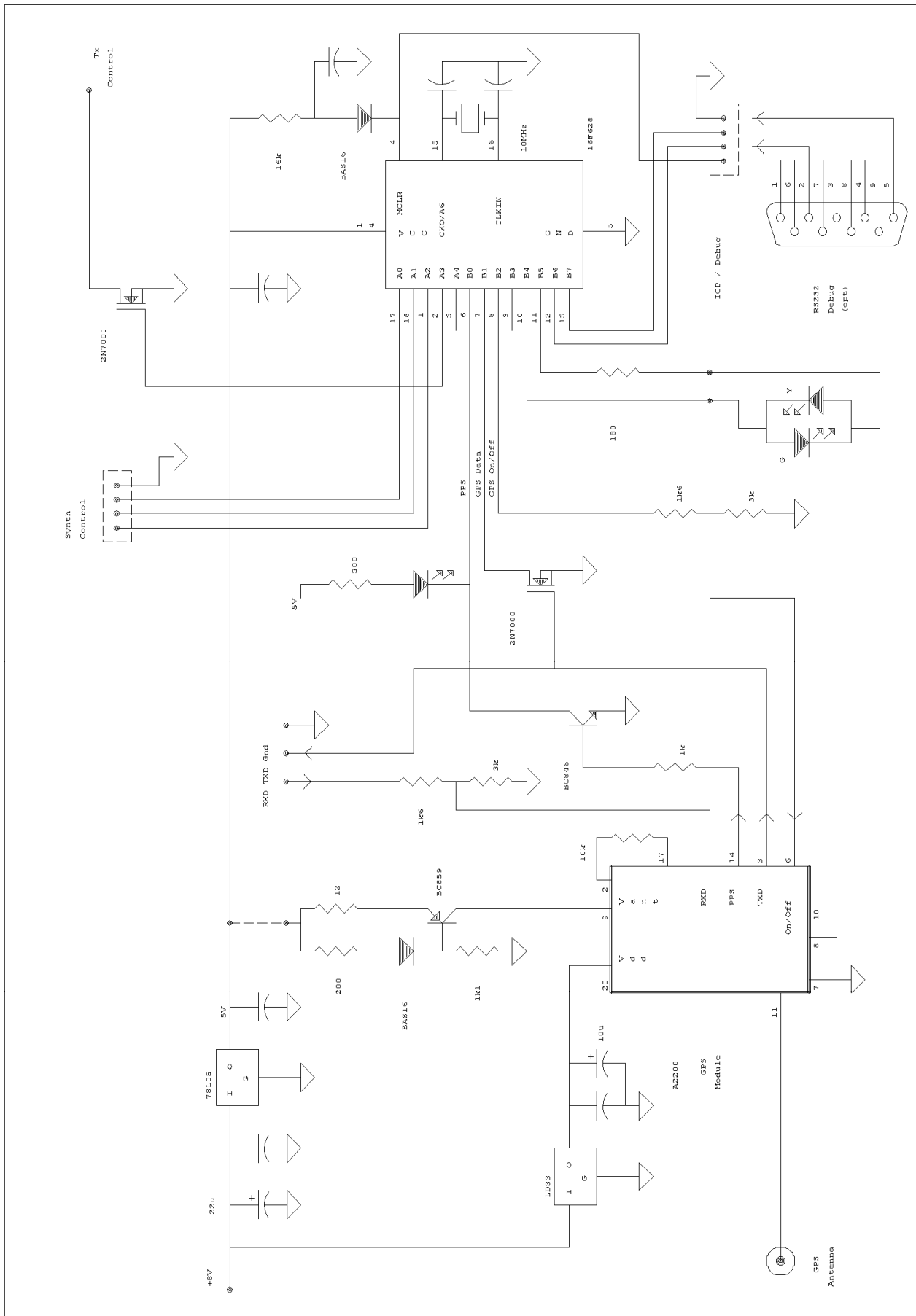
V/UHF Beacon Driver Module

This is described in more detail in [4]

This unit will amplify the output of the synthesiser chip to a level of up to 300mW.   The basic design is adaptable for frequencies up to 432Hz with few component changes

The first stage is a packaged modamp, an SGA6289, although other types could be substituted here such as the MiniCircuits PHA-1.   This drives a BFG591 which is capable of more than 20dB gain at 144MHz, so there is be plenty of scope for backing off and adding resistive loading to keep it stable and broadband.

To get 300mW output from a 12V supply means the final amplifier stage really ought to be designed to deliver 0.4W. The collector load therefore needs to be 122 / (2 * 0.4) = 180 ohms.   This is transformed to the 50Ω output impedance by the two-capacitor tapped network. The residual reactance in parallel with the transformed load resistance is then tuned out by a ferrite-cored inductor.   Adjusting the value of this inductor allows it to then absorb the reactive components of the transistor and the heatsink pad.   The Q of the output network is only about 7, so the matching is not critical and is reasonably broadband.   To facilitate backing-off of drive level to optimally match the high power PA stages, a preset resistor can be included in the emitter. Class-AB biasing is used, with a diode in thermal contact with the transistor to keep the bias stable with temperature.   Dissipation in the output device at full power output is around 1 Watt. The datasheet for the BGF591 allows 2 Watts maximum with a heatsink at room temperature, so it is operating comfortably within a safety margin.

UHF Version of the Driver Module

Heatsinking for the BFG591 is formed from an area of copper PCB foil, relying on thermal conduction through the PCB substrate to conduct heat away to the groundplane and chassis underneath.   The shunt reactance from the extra capacitance of this in parallel with the transistor collector is then absorbed into the tuning inductor.

References

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

[2]   WSJT Modes on Beacons   http://www.g4jnt.com/JTModesBcns.htm

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

[4]   VHF Beacon Driver module   RadCom March 2013, *Design Notes* (page 34)

Figure 2   Driver amplifier (output matched for 144MHz)