# <u>Developing a 1296 MHz</u> <u>Beacon</u>

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# **Stage Functions**

- Oscillator Module
- Multiplier Module
- Amplifier Module
- Keyer
- PSU Module
- Circulator/Filter

- A good start for an oscillator module is something that is available as a kit, or already built. There is little point in going to the time and expense of creating a PCB, and purchasing components, unless you are doing original development work for a special unit.
- A circuit in common use is the 2 transistor Butler Oscillator. This has been around since the valve days, and has been seen in RSGB Balloon Board, G4DDK oscillator series \* and the Minikits EME65 variants \*\*, as well as in some commercial designs.
- \* www.btinternet.com/~jewell/
- \*\* <u>www.minikits.com.au</u>

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• There are better oscillators, such as the Driscoll VHF oscillator and variants of the design such as the DISTAW, by Chris Bartram GW4DGU.

- I will go into detail about the oscillator module, because of its importance in the overall unit.
- The EME65B kit from Minikits in Australia was selected, due to its value for money.
- The oscillator circuit in the EME65 (B) appeared around 1981 in RSGB publications in the Microwave source of that era (<u>www.microwave-</u><u>museum.org/exhibits/mwm0018.htm</u>).

The RSGB oscillator circuit was liberated from a Plessey AMETS design used in balloons. The RSGB board was nicknamed the "Balloon board"

The original use was with fairly wide FSK (frequency shift keying), and the component values are associated with that.

The circuit hasn't really changed in the last 28 years (!)



This is the standard EME65B unit as received from Minikits. There were minor changes from the first EME65 version, with additional regulator filtering and a shielded coil for tuning the crystal oscillator.

The oscillator circuit consists of the Butler 2 transistor crystal oscillator. The second transistor collector is tuned to the  $3^{rd}$  Harmonic and the next transistor is used a further x2 multiplier. Output from the PCB is ~ + 10 dBm (10 mW)

The voltage regulator regulates the oscillator transistors. The final multiplier and PTC thermistor, for the crystal is run off the incoming +12V

- I have looked at this circuit, done some experiments and measurements and minimised unwanted noise and also improved frequency stability. Note that minimising unwanted noise improves frequency stability.
  <u>Sources of noise</u>
- Regulator noise
- Resistor noise
- Low Loaded Q of crystal.

#### Improving frequency stability

- Regulation of all stages
- Improved crystal heater

#### Miscellaneous changes

- Different biasing
- Changes to interstage coupling

**Regulator Noise** 

Typical Voltage regulators (78 and 317 series) are sources of unwanted noise due to the use of unfiltered zeners inside the regulator. Additional filtering is used to reduce this.

#### 100nF Electrolytic on Regulator output



#### 10 uF Electrolytic on regulator output

| CTR: 10.            | 3676Hz  | SPAN:   | 200    | kHz/     | REF:  | + Qe    | iBa       | 10dB/ |
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| RBN: 3              | OkHz8 V | /8¥t 10 | OkHz8  | SYF      | h 10a | S/8     | ATT:      | 10481 |

100nF Tantalum on regulator output



10 uF Tantalum on regulator output



10 uF Tantalum & (1000uF electrolytic!) on regulator output

| CTR: 10. 367G | z SPAN   | 200kHz/ | REF: + | Cd9a         | 10d8/ |
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| RBW: 30kHz@   | VB¥: 100 | kHz8 SV | 10mS/  | NT ATT       | 1048  |



The images are from the output of a 10 GHz source. The equipment consisted of G4DDK004 Crystal Oscillator/Multipliers with RF output on 2.5 GHz. The multipliers are x3,x2,x2,x2 This is then multiplied by a further x4 multiplier to provide output on 10.368 GHz. There is a 78L08 regulator for the 2 Bipolar Transistor Butler Crystal oscillator plus base bias for the following x2 multiplier. The images shows affects of different decoupling around the 78L08 regulator.

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#### **Resistor Noise**

There are several sources of resistor noise in the circuit. This is especially important around the Oscillator itself, as once the noise is there it cant be removed. The causes may be due to inadequate filtering and placement of resistors. Replacement of some resistors with inductors, improved filtering, and additional inductors have shown improvements.

Low Loaded Q of crystal.

The limiting of the amplitude is done by the transistors themselves, which drives the oscillator transistors out of class A, thereby increasing the source and load impedances seen by the crystal, hence degrading Q. Addition of clamping diodes across the tuned circuit removes the limiting function from the transistors bringing them back to class A. The low Loaded Q increases phase noise. (Unloaded Q is what the crystal is capable of, as a individual component, while loaded Q, is when the crystal is in circuit.)

Regulation of all stages.

If the supply volts change, then this changes operating points of unregulated stages, which changes the load on the oscillator, which can cause frequency shifts. Supply Volts changing can also result in output level variation.

Improved crystal heater

Crystal with no temperature control shows ~ 3 kHz drift when multiplied up to 1152 MHz when temperature goes from 10 to 50  $^\circ$  C

The use of the typical PTC thermistor as shown on slide 5, is useful as a first attempt. This should only be used on crystals specifically made to operate on that temperature (~ 55 ° C). Operates best if ambient temperature is constant, otherwise variation of thermistor temperature is high. 47 to 67 degrees C when temperature varies from 5 to 50 C. Frequency variation ~ 2.3 kHz

Checks with a W6PQL heater showed significant improvements, however there were stability issues. W6PQL Circuit was reworked, with operation similar to G8ACE design now showing improved results. About 3 to 4 degrees variation, with ~ 100 Hz variation at 1296 MHz

Miscellaneous changes to biasing and interstage coupling to optimise operation of oscillator and multiplier.

Information now on Minikits website





The Crystal oscillator runs at 108 MHz and is multiplied by 6 times to 648 MHz. There is at least 15.5 dB extra noise added because of this multiplying process This was taken via a Spectrum Analyser with Phase Noise Capabilities and results are probably compromised by the limitations of the instrument (1 kHz to 100 kHz or more) However the area between 100Hz and 1 kHz away from carrier shows significant change as the following slide shows



### Oscillator heater



Original configuration had voltage gain of 50 to 100 times, ~0.03 degree (1 ohm) change gave ~ 0.25 volt swing on output. Very touchy !! This circuit now has similarities to the circuit used by G8ACE in his OCXO's



Green is temperature of crystal. Blue is temperature inside Peltier chamber. Pink is drift of oscillator output.

No 2 Temperature run of unmodified EME65B & modified W6PQL heater with NTC Thermistor next to crystal



Green is temperature of crystal. Blue is temperature inside Peltier chamber. Pink is drift of oscillator output. Insufficient time during warmup period caused upward slope.

# Block diagram of Beacon



#### <u>Oscillator</u>

The oscillator is to be configured, so that ~ 100 MHz @ ~ 0dBm is present on the output of the EME65B PCB. This allows replacement with units such as the G8ACE unit, and reduces interaction between oscillator and multipliers.

There is some small frequency control, using a varicap, to allow for frequency adjustment, due to crystal aging, or to allow disciplining.

Regulators off the Oscillator enclosure, so that only heating is done by the W6PQL unit.

108 to 648 MHz multiplier

Another modified EME65B (ie minus the crystal) is used as the 108 to 648 frequency multiplier. The modifications as discussed before are still mostly applicable to reduce noise and improve voltage stability.

Small attenuator Pad to reduce level.

648 to 1296 MHz multiplier

Uses ERA-3 MMIC, on a Waikato VHF Group filter PCB. (~ +7 dBm or 5 mW)

#### Attenuator/Pin switch

This first attenuator is used to set drive levels for the subsequent stages. A PIN switch is keyed to reduce drive level in the off state, and additionally it ensures that the following active stages don't have RF on them, during keying. There is another attenuator on the output of the switch, to reduce the output impedance change when the PIN switch is keyed.

#### <u>1 Watt Amp</u>

The Minikits EME162 Amplifier allows a drive stage to be added, and in this application, a ERA-2 MMIC was added for additional gain. There is some minor



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changes to increase volts on the Output FET slightly. Power output in excess of +29 dBm. These 2 stages are switched on and off by the keying. Cooling is by a stick on heatsink. This could be used as the final stage, however for more power...

#### **Output Amplifier**

The RF Device could be either a Mitsubishi MGF0907 or Toshiba FLL120 10 watt FET. (available at low(ish) cost on the surplus market)

Positive DC Supply was going to keyed with DC current set to ~ 2A, but changed so that device is biased in Class AB, and driven up with RF Drive.

Greater efficiency than a Mitsubishi Power Module.(~ 50 % vs 25 % ! )

Will have PSU interlock so will not put Drain Volts on without - 5 volts, otherwise FET will very quickly become a 3 legged fuse.

#### NOTE

Mitsubishi DO NOT recommend frequent ON-OFF keying of their power modules LDMOS FET's and surplus amplifiers are becoming available as well.

Circulator and Bandpass filter (BPF)

I have circulators and BPF's from surplus equipment. The circulators will retune to 1296 MHz, with strong magnet from faulty PC Hard-drive.

The BPF's have multipole construction, and tunable notches that can reduce adjacent 108 MHz products further.

#### <u>Keyer</u>

I was looking for a suitable keyer, with multiple features.

I came across the ID-O-Matic, which can be (re)programmed via a PC Serial Bus

Features :-Variable keying speed Programmable delay Audio (MCW),CW and PTT Outputs Also useful in Repeater Applications US\$20 From NOXAS

http://www.hamgadgets.com/



#### Regulators

Most of the regulators are conventional 7808 or 7805 regulators, however the regulator for the PA, will be LDO (Low Drop Out), due to higher voltage (10v). The current requirements are higher so a LM1085 3A version, or LM1084 5A version is selected.

Ensure adequate heatsinking. I have seen regulators show thermal shutdown, if run for long periods of time (15 to 30mins)

### **Additions**



Used GPS Disciplined Oscillators (GPSDO) such as the Trimble Thunderbolt shown left can be used in a Oscillator locking scheme such as suggested by G4JNT (<u>http://www.g4jnt.com/LckdSrcs.pdf</u>) see figure 3. The use of a DDS like that by Mini-kits will be necessary in this application. Alternatives are REFLOCK units by CT1DMK and VE1ALQ

Note this project is a work in progress. Kevin ZL1UJG