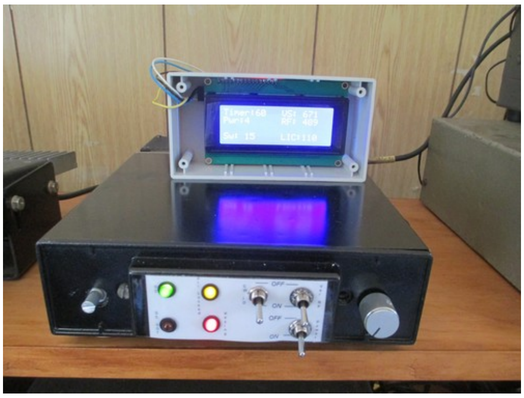
28MHz SARS Beacon Project

11January 2016



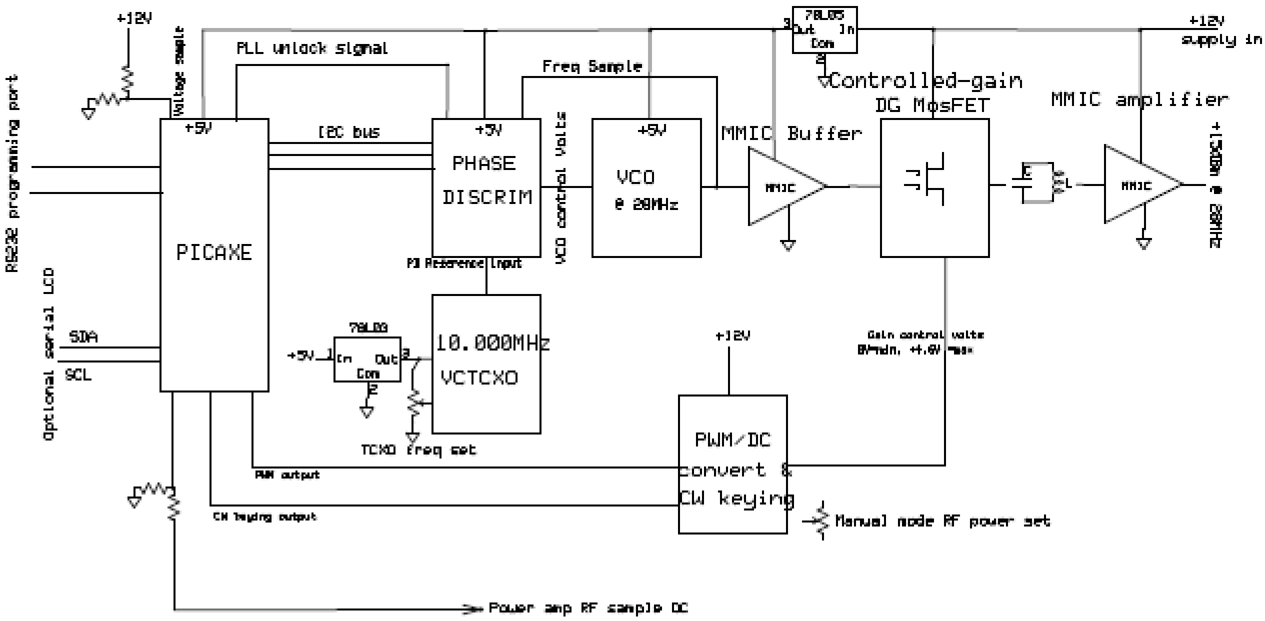
You may have come to this website if you have heard a beacon using the callsign VK4ADC/B on 28.211500MHz (previously on 28.220) and want to find out what it is & where it is.

T**he VK4ADC/B callsign is a temporary one** until it is moved to its eventual destination of Mt Cotton towards Moreton Bay from Brisbane City.

The beacon is here at my home QTH (New Beith, 4124) for now as it is in the burn-in phase before it gets placed up on Mt Cotton. It will probably get a callsign change at that time to VK4WSS as the beacon is for the Southside Amateur Radio Society and will be co-sited with their VK4RAX 2M repeater.

It is now powered from my solar-charged batteries so is a 24x7 beacon until the location change, except when placed on dummy load for any further "tweaks". It is stabilised by a 10MHz VCTCXO and should maintain frequency within 1-2 Hz after the current burn-in and the frequency is reset back to 28.211500.

The exciter is one that I have designed from scratch using surface-mount parts so is not a modified board from anywhere else. The only parts on the board not SMD are the VCO coil, the 0.1" header pin connectors and the tuned interstage transformer between the controlled-gain amplifier stage and the output MMIC stage. The board itself is double-sided but only one side is laid out, the other being used as a ground plane. I started the PCB layout in November 2015 and built two prototypes while I explored the synthesiser and RF power control techniques. The final PCB version is V1.0F so it shows that a number of variants that have not actually been built. A general description follows later.



PDF of the block diagram is here (/~vk4adc/web/../UserFiles/Image/28bcn/28MHz beacon exciter block 11Jan16.pdf)

The antenna is currently a 1/4 wave whip based about 2.5M above ground, so is vertically polarised and without gain. I understand that it will run on a re-tuned CB whip when in its final location, so still vertically polarised and still no gain.

This beacon has been constructed in such a manner as to provide an advanced radio propagation tool. It varies the RF output power in a sequential manner so that signals can be observed and a determination of path quality made by a listener.

The exciter section of the beacon utilises a PICAXE-controlled frequency synthesizer at the final frequency, in the current case at 28.2115 MHz, followed by a MMIC-style broadband amplifier then a tuned gain-controlled stage and finally another MMIC stage to produce about +15dBm at full output. The 28MHz RF from the exciter board is then fed into a MMIC driver stage on the PA PCB then in to a RD16HHF1 power amplifier FET and then via a simple Pi-network LPF to the BNC antenna port. There is no frequency multiplication involved with the PLL running at the transmitter output frequency.

28MHz SARS Beacon Update : 21 July 2016

The ID cycle for the amplitude keying and power sequence has been altered to the following:

0 to 6 seconds: Fast CW identification (20WPM), short callsign only at highest achievable RF power level (>5 watts), followed by a brief pause

7 seconds: Carrier only at power level 9 (5 watts, reference RF level i.e. 0dB) for one second

8 seconds: Carrier only at power level 8 (2 watts, -4dB) for one second

9 seconds: Carrier only at power level 7 (1 watt, -7dB) for one second

10 seconds: Carrier only at power level 6 (0.75 watts, -9dB) for one second

11 seconds: Carrier only at power level 5 (0.5 watts, -10dB) for one second

12 seconds: Carrier only at power level 4 (0.25 watts, -13dB) for one second

13 seconds: Carrier only at power level 3 (0.1 watts, -20dB) for one second

14 seconds: Carrier only at power level 2 (0.05 watts, -23dB) for one second

15 seconds: Carrier only at power level 1 (lowest RF power level, about 0.01 watts, -30dB)

16 to 19 seconds: Sequence pause - carrier only at power level 1 – note that the carrier is not completely switched off. If you can hear this level then propagation between the beacon and you is extremely good!

This 20 second cycle then repeats with the full CW identification including grid square information every 6th time.

Notes:

1. All RF power levels have been calibrated into a true 50 ohm load. Variations in antenna impedance may cause the final power level to change BUT the relative power ratios will remain about the same.

2. The above power ranging allows the received signal to vary about 30-40dB e.g. from S9 (at the 5 watt power level) down to below S0 (at about 10mW) on a typically calibrated S-Meter.

3. The CW identification is expanded approximately every 120 seconds so that the grid locator is transmitted along with any low supply voltage (LV) or high supply voltage (HV) status alarm.

4. The beacon undertakes an RF output recalibration approximately every 30 minutes and this becomes evident in that the received signal level is seen to cycle upward (rather than downward as happens during the normal ID cycle). The RF output recalibration also occurs immediately after DC power is applied to the beacon and prior to the normal 20 second ID sequence commencing.

The power levels are self-recalibrating in that the RF output is sampled by a peak detector circuit before the output LPF and fed back to an analogue-digital (A/D) function in the PICAXE. That value is used to vary a PWM duty cycle to adjust the controlled-gain stage to achieve a preset target value. The target values have been determined by running the beacon in a manual power mode into a 50 ohm power meter and the A/D values noted. If the RF power is either higher or lower than it should be at any stage in the power level-switching process, the software recalibrates back to achieve the correct target value. It should maintain the power levels accurately even in the face of ambient high temperatures or even long term ageing effects.

To reduce the software overhead during the timing cycle, the raw PWM values are stored in EEPROM once determined for each power setting and updated only if they change significantly. These values all start at zero as the beacon software is first run and are saved during the initial power calibration process. It seems strange to see the RF power meter start at zero and then slowly rise to the preset power, drop to zero again, slowly rise again etc. The power calibration phase is then completed and it starts its normal timing cycle for power level shifting with its morse identification.

There can be additional letters added to the full identification if the supply voltage is regarded as being out-of-tolerance (OOT. If the power supply voltage is greater than 14.4V or lower than 12.0V then the letters HV or LV respectively are added. " The OOT options were added as the long term installation is likely to have at least part-time solar-charged batteries.

The PICAXE chip monitors the PLL "lock" signal and disables the RF output immediately if the 'locked' status disappears. It will try either just re-programming the PLL chip itself a number of times to see if the PLL re-locks or doing a full system restart if a specific attempt loop count is encountered. In this way, the beacon cannot just wander around in frequency and produce RF & QRM on someone elses frequency.

An additional input has been fitted to the exciter to allow a remote signal to disable the RF output. The application of +5V to +12V (at 0.5 to 1mA) on this input will cause the beacon RF to shut down. It wasn't part of the original design and has been fitted as an afterthought using some PCB tracks and pads that aren't specifically needed. This connection is on the 5-pin DIN socket at LHS rear, under the PA compartment and shares the connector with the optional serial LCD display.

The board was also designed to allow for an external 10MHz reference source to be connected and internally switched to but this has not been implemented. The BNC on the rear underside is connected to the internal VCTCXO reference to allow external calibration of the frequency to 10.000000 MHz using the front panel potentiometer (LHS, slotted & no knob).

The RHS front panel potentiometer is used to vary the RF output power when in 'manual mode' - achieved by shifting the red jumper on the 3-way strip immediately behind the front panel. That allows the AD value from the PA sample to be read and the calibration values at 1, 2, 5 and 10 watts to be confirmed.

The three way terminal strip on the PCB towards the front RHS is used for the connection of an RS232 port for programming the PICAXE chip and is not required as an external case connector.

Further Notes : The original FM828/25ER power amplifier section was removed in July 2016 and replaced with a new version using a RD16HHF1 PA device. This device is for linear use at HF so solves some of the problems associated with low drive levels to a chain of Class C power amplifier devices. The quiescent current on the RD16HHF1 stage is only 35mA, provides good gain, but its use limits the actual maximum RF output level to about 7 watts at 28MHz. The maximum power step has been set to 5 watts as a result.

http://www.mitsubishielectric.co.jp/semiconductors/content/product/highfrequency/siliconrf/discrete/rd16hhf1.pdf (http://www.mitsubishielectric.co.jp/semiconductors/content/product/highfrequency/siliconrf/discrete/rd16hhf1.pdf)

The Australian LCD (2015) for amateurs states :

7A Spurious emission limits for an amateur station

(1) The licensee must not operate an amateur station if the emissions of the station include spurious emissions that are not attenuated below the power of the wanted emission supplied to the antenna transmission line by:

(a) for frequencies less than 30 MHz — the lesser of:
(i) 43 + 10 log (PEP) dB; and
(ii) 50 dB; or....

The aim is to exceed the specifications and that means the maximum spurious or harmonic outputs should not exceed –44dBc (dBs below carrier level at full output).

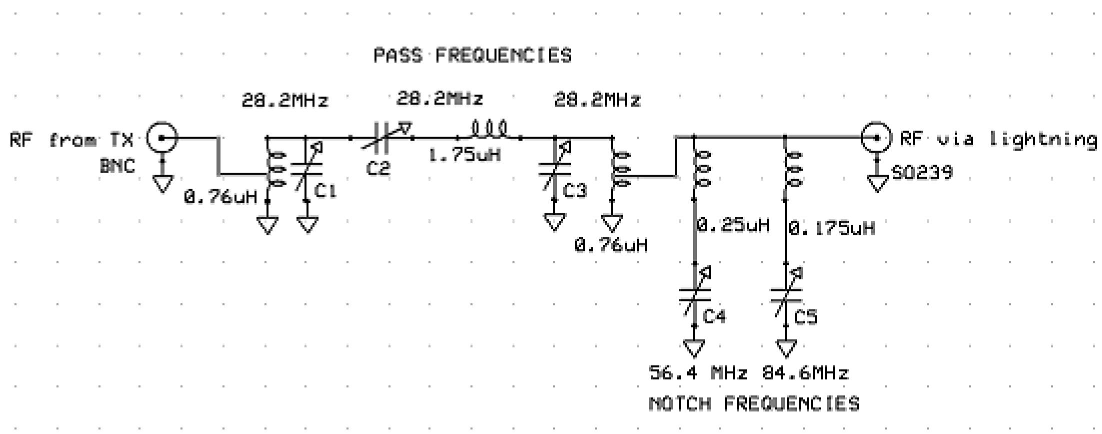
The frequency of 28.211500 is not set in concrete and was selected taking note of other 10 metre beacons mainly in Oceania and the USA. It could be changed by re-programming the divisors in the synthesiser but the Australian WIA (see http://www.wia.org.au/members/beacons/about/documents/GUT2%20Beacon%20Guidelines%20140311.zip (http://www.wia.org.au/members/beacons/about/documents/GUT2%20Beacon%20Guidelines%20140311.zip) from the web page http://www.wia.org.au/members/beacons/about/ (http://www.wia.org.au/members/beacons/about/)) wants new continuous mode beacons to operate between 28.201 and 28.225 MHz and this frequency is in accordance with that requirement.

At a meeting of SARS on 20 January 2016, it was agreed that the frequency suggested by Andre DL8WX as being clear in Europe be implemented. The frequency was changed from 28.220 to 28.211500 on 21st January 2016.

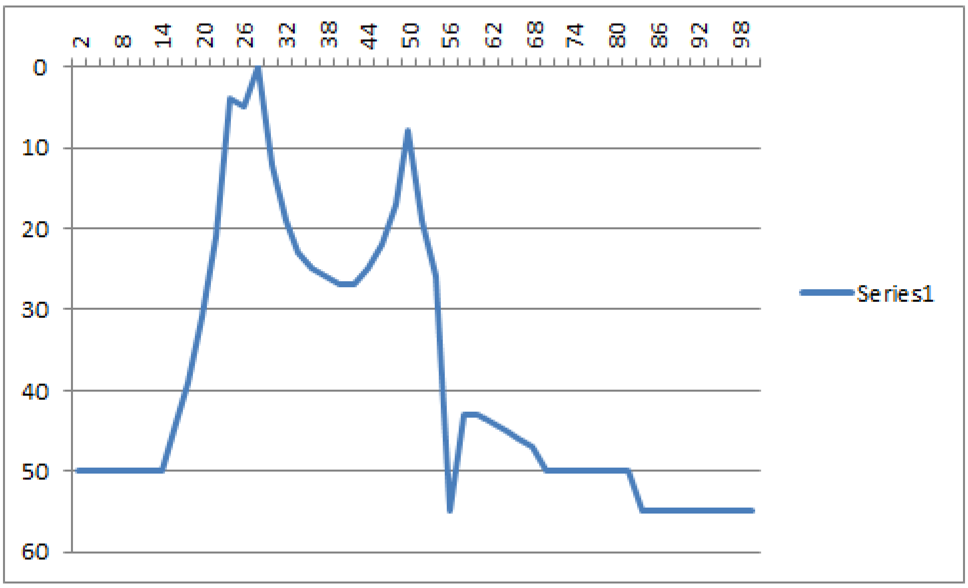
23 Jan 2016:

We have been advised that the beacon needs to have a bandpass filter fitted between the transmitter and antenna. The site is regarded as a communal radiocommunications site with several transmitters and receivers on the same site plus multiple repeaters and base stations throughout VHF and UHF on nearby communal sites up on Mt Cotton and this introduces the BPF requirement. It should be noted that this is primarly to prevent other VHF/UHF/microwave transmitter's output signals from penetrating the beacon transmitter PA stage and causing intermodulation products. Given I had already included a 3-section LPF with fc = 32MHz in the PA compartment and that this will be the lowest frequency transmitter installed on Mt Cotton, one has to wonder if it is really necessary.

It has also been stated that there needs to be lightning protection fitted into the antenna feedline.



FILTER SCHEMATIC



FILTER RESPONSE CURVE, dB Insertion Loss versus Frequency in MHz, after adjusting for best return loss.

The test configuration "bottomed out" at around 50dB for accurate value measurements but the values of loss were somewhat higher, particularly at the 56 and 84MHz notch frequencies.

The rise around 50MHz only appeared when the two notch filter sections were added but since there are no commercial transmitters around that frequency on Mt Cotton, intermodulation issues should not arise. Remember also that there is a 3-stage LPF with Fc=32MHz inside the output section of the beacon transmitter itself.

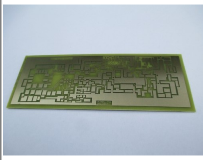
One of the interesting effects is that of metal-tipped alignment tools. I am now using a fully-fibreglass tool for all adjustments as it is amazing just how much effect there is just using the metal tip on even a "grounded' capacitor shaft, but particularly on the series trimmer, C2, and the notch trap capacitors C4 & C5....

The tuning of the BPF is critical *and the procedure to be followed should be adhered to exactly. In step-by-step form, it is listed here:*

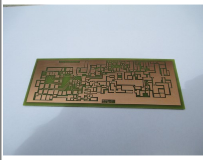
- *Feed a sig gen at 28.2MHz into the input port, spectrum analyser on the output port – in my case I added a 6dB 50 ohm attenuator in the output port lead to ensure that the 50 ohm impedance is a constant.*
- *Adjust C2, the series LC trimmer, for minimum output at 28.2MHz.*
- *Feed in the sig gen via a 2.2K, 2.7K or 3.3K resistor.*
- *Terminate the output port in 50 ohms and add a 1-2 turn coupling loop to the spectrum analyser flylead – my coupling loop is terminated on a BNC socket for easy access/use.*
- *Loosely couple the loop to the input coil and tune C1 for maximum signal on the analyser display.* Once adjusted this setting is not touched again.
- *Reverse the connections to the BPF so that the sig gen is now on what was the output port and is now the input port.*
- *Feed in the sig gen via a 2.2K, 2.7K or 3.3K resistor.*
- *Loosely couple the coupling loop to the (now) input coil and tune C3 for maximum signal on the analyser display.* Once adjusted this setting is not touched again.
- *Return the input and output connections as normal, sig gen in and analyser on the output port - removing the series resistor from the generator feed.*
- *Adjust C2, the series LC trimmer, for lowest insertion loss at 28.2MHz – OR – preferably, the best return loss figure.*
- **Do not re-touch either C1 or C3 at any time, only “tickle” C2 for return loss.**
- *If the 56 and 84MHz notch filters are fitted, then sig gen in at the relevant frequency, spectrum analyser on the output and tune for deepest notching of the displayed signal.*
- *If you don’t have facilities to measure return loss, connect a 28MHz transmitter at low power via an in-line SWR meter and terminate the BPF into a 50 ohm dummy load. Adjust C2 for the lowest SWR value reflected back to the transmitter.*

Just a few photos of the beacon unit (as at January 2016). Mouse-over to see more detail.

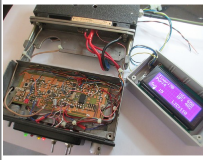
Front panel indicators and control switches. LEDs for power on (green), PLL locked (yellow), supply voltage OOT (red), CW Keying (orange). Switches for DC on/off, CW keying on/off and RF power level changes on/off. Normal operation is with all switches in the down positions.



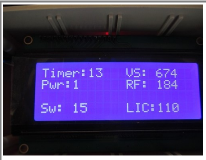
The PCB directly after exposure, developing, etching.



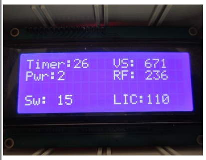
The PCB cleaned off & ready to accept the parts.



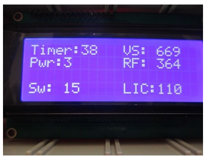
The exciter PCB installed into the front compartment of the FM828 chassis. The LCD has yet to be properly fitted into the sam size of jiffy box - but black in colour !



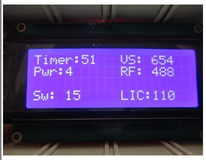
LCD display showing values for the 1 watt condition.
Note the raw VS AD value at top RHS and compare it as the power level is increased....



LCD display showing values for the 2 watt condition.



LCD display showing values for the 5 watt condition.



LCD display showing values for the 10 watt condition.

Note again the raw VS AD value and compare it to the 1 watt state. It shows the voltage drop in the power leads.....

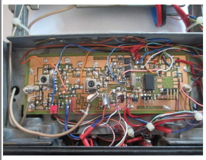
For info, the AD values versus actual voltage look like this:

12.0V++ = 591, 12.5V= 616, 13.0V= 641, 13.5V=666, 13.8V=681, 14.0V=705, 14.4V**=711

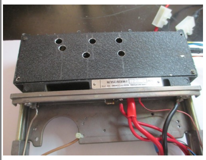
The values marked with ++ and ** denote the values before the OOT LED lights and the additional letter sequence is added to the full CW ID.

The SW: 15 value only changes when one of the front panel toggle switches change state and this also reflects in the LIC: value changing from 110 to 010, 100 or 001.

Front view showing TCXO freq adjustment pot on LHS (no knob) and the manual RF power control (with knob) on the RHS



Top view of the exciter PCB.
Picaxe at RHS, synthesiser around centre top, TCXO at centre bottom, controlled-gain stage to LHS of top centre, MMIC output stage at LHS end of the PCB. Only two 10mm square inductors (raised above PCB) are used, the one towards centre is the VCO coil and the one at left is tuned to 28MHz as a tuned transformer.



PA compartment with the "tuning" cover in place. The holes allow access to the interstage trimmer tuning capacitors. There is another cover without the holes that will replace the one pictured.

11 January 2016: Beacon signal reports in from VK3 & VK5

Email dated 15 January 2016:

"Doug,

This morning at 0900 UT I could cpy ur new beacon on 28220 kHz for the first time, very weak with S2. 5B4CY was not audible at that time.

Due to the low signal I did not wait for identifying the pwr level at that moment but the signal here will improve providing better reception windows when you have moved the beacon.

I was really astonished that even the present preliminary qth did provide a path to Europe.

I'm listening with a 3 ele beam and the TS-590SG. My location is nr Koblenz, in JO30WE.

Pse inform me when you put the beacon to the final qth.

Tnx fer starting it with so much design work es 73!

Andre DL8WX

"

Visit Andre's web site HF beacons page at http://www.dl8wx.de/baken_kw.htm (http://www.dl8wx.de/baken_kw.htm)