198kHz Off Air Standard

By G8MNY (Updated Nov 16)
(8 Bit ASCII graphics use code page 437 or 850, Terminal Font)

I can no longer use my TV locked reference system (see my buls on "Off Air lock for Ref Osc") for calibrating RF gear, as analogue TV has ended. So I took the opportunity at a rally to buy someone's old homebrew (cheap) veroboard construction version of the BBC 198kHz LW off air reference project. (from a Practical Wireless article Dec 1995 by G8JVE, to go with the Robin counter & follow up Oct 1998). The divider chain in this design have had a rearranged (different to article) to give more useful reference frequencies see below.

```
LAYOUT                                     AE       Mains   12V
                                          ┌┴┴──────────────────────────────────┐
  ┌─────────────────────────────────┐     │      │~Trans- ~│  │~~PSU~~~~~~│    │
 ╓ÁExternal Active Ferrite Rod Aerial│     │      │ former  │  │   board   │    │
 ║└─────────────────────────────────┘     │      ~\_____/~   └───────────┘    │
 ║                                         │ ┌────────────────────────────────┐ │
┌õ──────────────────────────────────┐     │ │  RF    Mixer  IF   Det  OpAmp  │ │
│   Manual             Ref Freq    │     │ │ Buff    IC    LC          IF   │ │
│ o   .-.    ┌───────┐   .-.      │     │ └────────────────────────────────┘ │
│Power(   )  │ Meter │  (   )     │     │ ┌────────────────────────────────┐ │
│ o   '-'    └───────┘   '-'      │     │ │10   Buff  Counter Counter Phase│ │
│ o    '-'    CZ =o  Sig   '-'    │     │ │MHz   IC     IC      IC   Comp IC│ │
│ ¡        Not o    o Lock     (¨)│     │ └────────────────────────────────┘ │
└──────────────────────────────────┘     │ SW   Pot      Meter      SW   BNC  │
                        Ref Output        └──────────────────────────────────┬┬┘
```

This "type of design" might be usable in other parts of the world if there are suitable accurate LW or MW stations.

OPERATION PRINCIPLE

```
          SPECTRUM          Carrier            Rx                    Extracted
                               │             Image!                   Carrier
           LSB MOD          PSK█PSK      USB     V                       │
  /~~~~~~~~~~~~~~~~~~~~~~~~~~\█/~~~~~~~~~~~~~~~~~~~~~~~~~~\              │
─┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼───┼──>Freq  ──────┼──────
191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 kHz    198.00000
```

As you can see from the spectrum, extracting a pure clean carrier is not quite as straight forward, when there is phase shift keying to remove too. (PSK in UK is used for power meter control?)

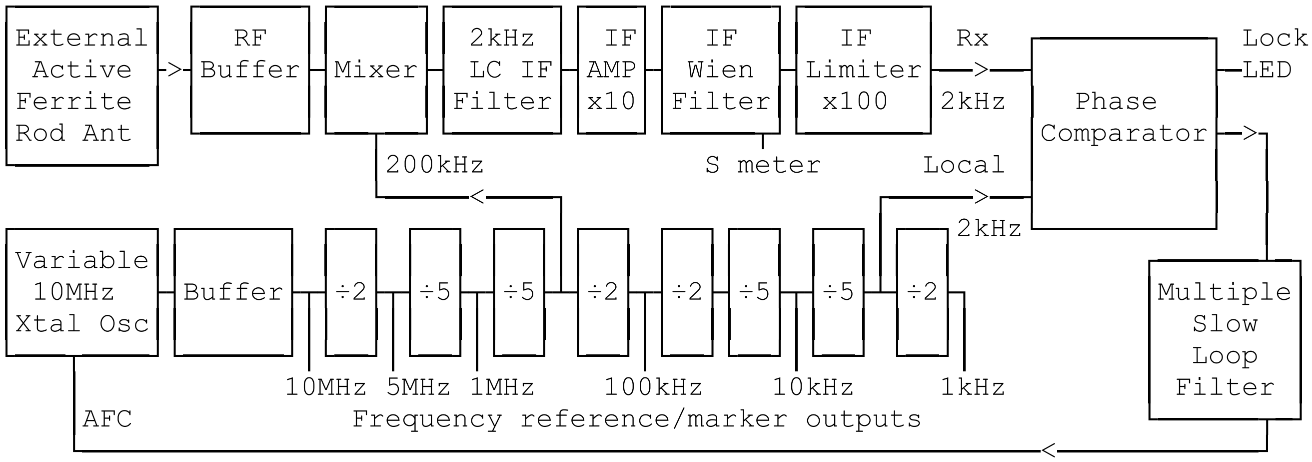
A close-up should look something like this..

```
                        │
~~\              ▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓             /~~~
      ┼         ┼               ┼         ┼
──────┼─────────┼───────┼───────┼─────────┼──────>
     -20       -10      0      +10       +20     Hz
```

Where the PSK data sidebands cover the carrier, the data is encoded to have no mean carrier offset. But no amount of sideband filtering will remove the PSK in practice, but using a very slow PLL loop filter of a fraction of a Hz, it will then be get ignored.

So from this 198kHz (it used to be 200kHz a Standard Frequency Transmission, until it had to conform to 9kHz EU region standard!) you can extract phase control for a reference frequency oscillator.

SCHEME



By using a low 2kHz IF, the superhet's unprotected image is @ 202kHz or @ 4kHz of USB content. This will affect the phase & level stability of the extracted carrier!

With this scheme it is important that the RF aerial tuned circuit & both the LC & Wien filters, in the IF are properly centred on frequency, otherwise residual AM will give asymmetrically phased sidebands resulting in apparent carrier phase modulation. As it is the carrier's frequency we want, this is bad news!

WHY WAS MY UNIT CHEAP?
Well it sort of worked, but there was far too much Phase Shift Keying on the reference output following the low speed PSK DATA on the 198kHz broadcast. As well as that it was quite insensitive despite an extra RF buffer stage.

FAULTING
On testing with a scope I found the mixer was hard clipping very early, I found it was incorrectly biased, & carefully following the circuit on the board this was due to an uncut stripboard track!

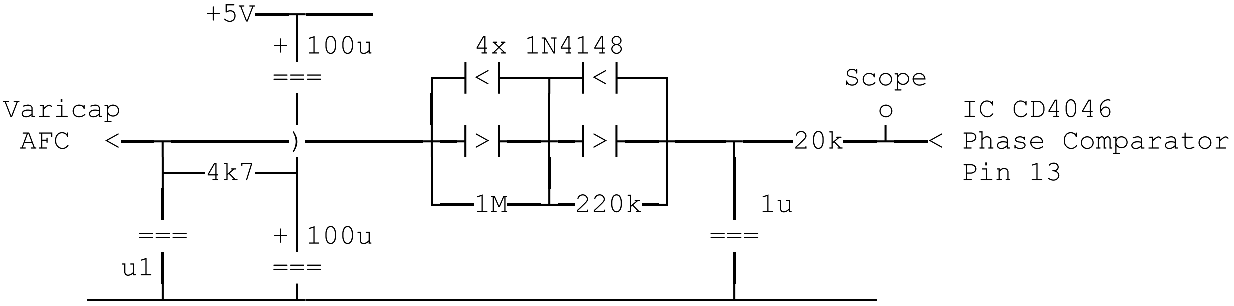
The RF buffer was rebuilt to a simpler less lossy circuit. (see 6/ below)

The problem with the PLL I initially solved crudely with a 100uF & series 2k2 across the AFC line, then it gave a steady 10MHz note after a long lockup time.

IMPROVEMENTS
1/ MIXER
I also noticed with the scope there was 2kHz IF beats on several of the Mixer bias points, I changed decoupling capacitors from u1 to u47 & reduced this.

2/ PLL FILTER
Looking into the PLL jitter problem, there was a very high Z circuit using a 40 Meg ohm (4x 10M) as the R for a 40 second time constant. This obviously was not working correctly on this layout, possibly due to leaky old PCB or varicap diodes? (also discussed in the designer's follow up article)

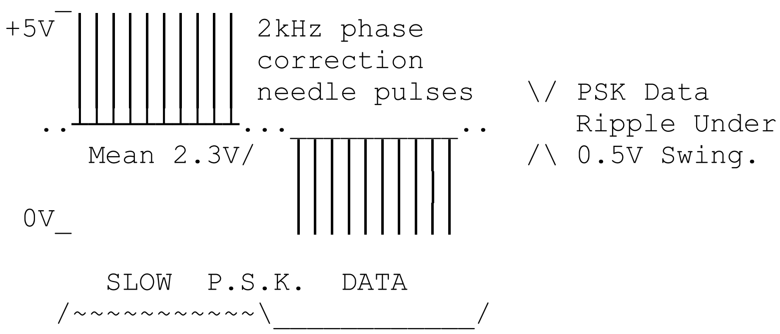
Anyway I redesigned this bit using electrolytics, something avoided by the original designer. But by using 2 identical electrolytics in series across the well regulated 5V power rail, I solved most of the leakage problem & gained instant half rail AFC voltage on power up, for a faster initial lock up time.



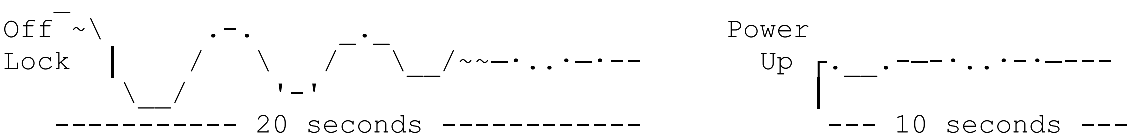
I enhanced the variable CR system with 2 more diodes & another resistor, so initially PLL out of lock you have 20k + 200uF for a 4 Sec time constant, then at ±1V from lock it adds a 220k for a 50 Sec time constant, & at less than ±0.5V a further 1M for a 200 Sec "properly in lock" time constant.

The starting 20k + 1uF (20mS) is needed to remove the 5V 2kHz IF pulses & reduce the residual 12.5Hz Phase Shift Keying data to below 0.5V ripple. This however is a loop time constant that will oscillate, so I added a 4k7 in series with the larger Cs to damp this oscillation, but the 4k7 is not big enough to let much of the PSK data through to the AFC line. The u1 is used close to the varicap diodes & keeps down any stray clock pickup/noise etc.

At lock, using the scope point with a x10 probe or on AC, & locked to a fraction of 50Hz mains (e.g. 12.5Hz) you see.

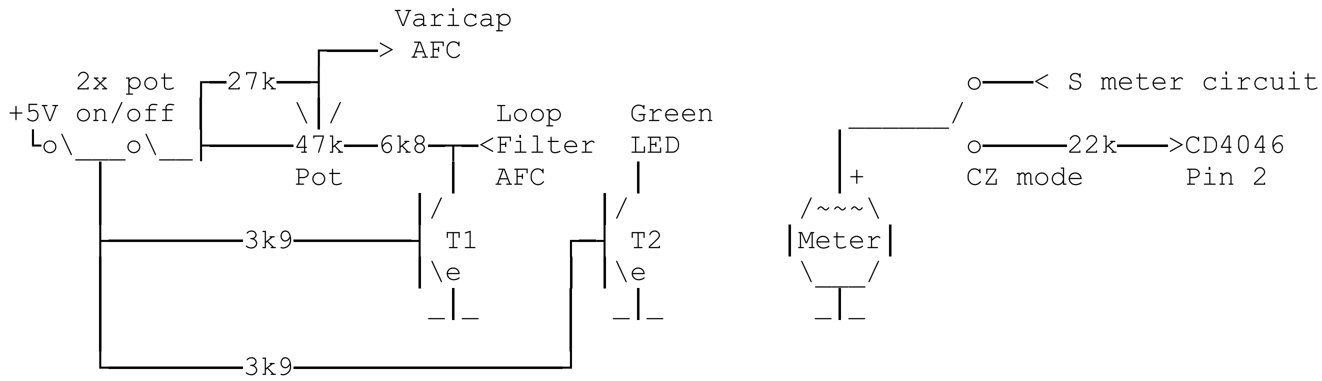


The PSK data pulls on the stored AFC voltage several times a seconds. A steady 2.3V is obtained with Xtal trimmer preset. With an SSB Rx you can hear the 10MHz oscillator (or harmonic of other outputs e.g. 29x 5MHz =145MHz) settle down to a stable note after several diminishing 4 second cycles.



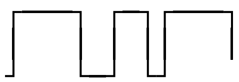
3/ MANUAL TUNE
There was an ugly hole in my box & a S meter/centre zero meter & switch fitted. So I developed a circuit for these, to provide a manual Centre Zero mode with a pot to fill the hole. (I did not have the follow up article then!)

The log pot (old Volume control) I used had a double make on off switch, & I needed a changeover. Leaving the pot in circuit & using T1 to short incoming AFC line I achieved the same function, & T2 shorts out the Green in lock LED to indicate it is in manual off lock mode.



As the pot was a log one the varicap angle-frequency action was not quite linear (needed square law?) so 27k was put from the max end to centre & 6k8 to the switched ground, this gave a really even feel to the offset (±5Hz @ 10MHz) with 2.3V at the centre position.

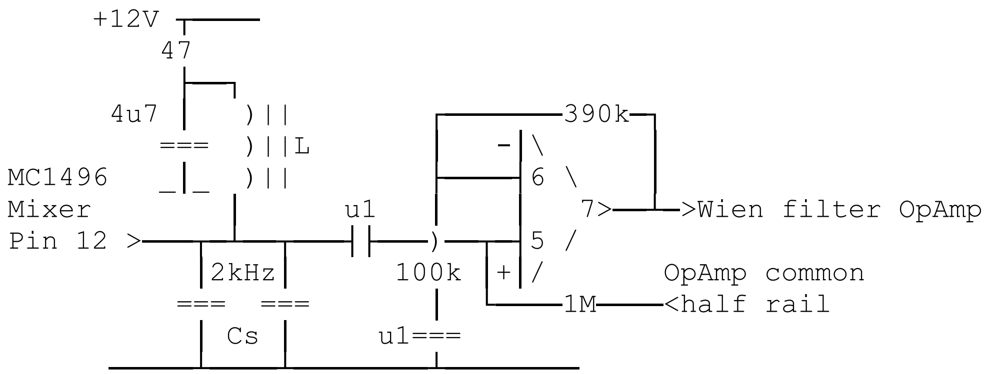
The Centre Zero meter action was taken from pulses directly from the unused IC pin 2 via a 22k, to set the meter sensitivity. If you scope that pin you see...



The average changes a little depending on the two 2kHz phases.

4/ 2kHz IF LC FILTER Q

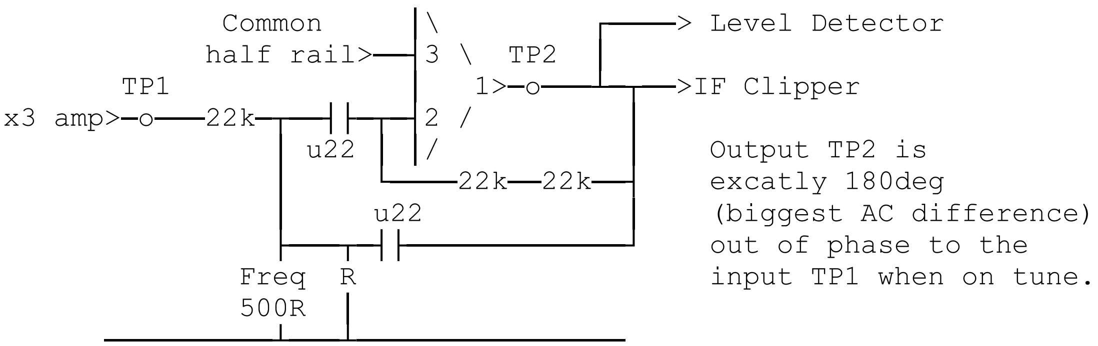
I found the LC filter after the mixer was heavily loaded by the OpAmp 10k circuit negating the high Q & narrow bandwidth possible, this may have been partly due to different component values. Anyway I rewired the OpAmp for high Z input & reduced the gain from 10 to 3.9, to stop it clipping, now the Q is much greater (narrow bandwidth equals much less of the broadcast AM on the 2kHz IF!)



After experimenting with the 2 Cs values for exact resonance of the L, the 1MÛ OpAmp bias R does not load the tuned circuit, & the much better filtered IF signal now has very little AM left on it. So the following Wien filter has less to do to extract a clean carrier. But I did look at that too..

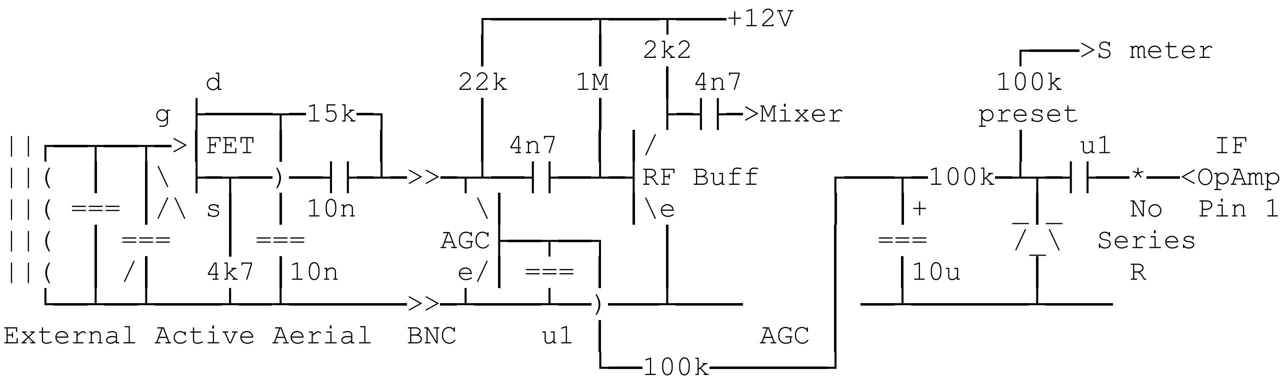
5/ 2kHz IF WIEN IF FILTER

The OpAmp has a gain of half, so it can be driven with a clipped signal from the earlier OpAmp before its output to the level detector clips. By changing the feedback R from a 22k to 2x 22k the gain is then 1 & the output to the signal detector is true until the Wien OpAmp clips. The Wien filter Q is also doubled, bringing the total IF bandwidth down to about ±20Hz. The frequency setting preset needs to be about 350R, so a suitable R across the multiturn preset to provide this value at the centre of the preset is ideal.



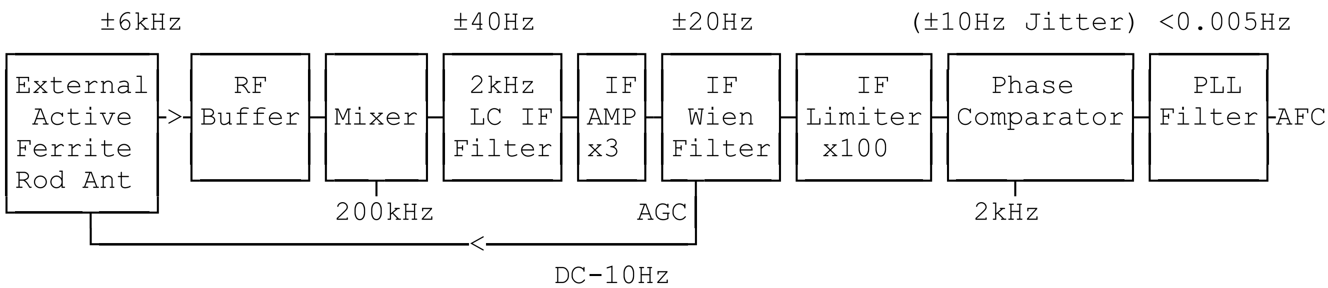
6/ Rx AGC

I found the mixer & other stages could overload & possibly add phase modulation from the AM signal before the signal was tightly filtered, so I added an AGC. I did not want to remove RF buffer's gain, as this is useful when in buildings with weak signals etc. So I used an additional NPN to short out the external FET preamp's supply, this gave a very good AGC, with no distortion from AGC action & gave the S meter with usable log scale.

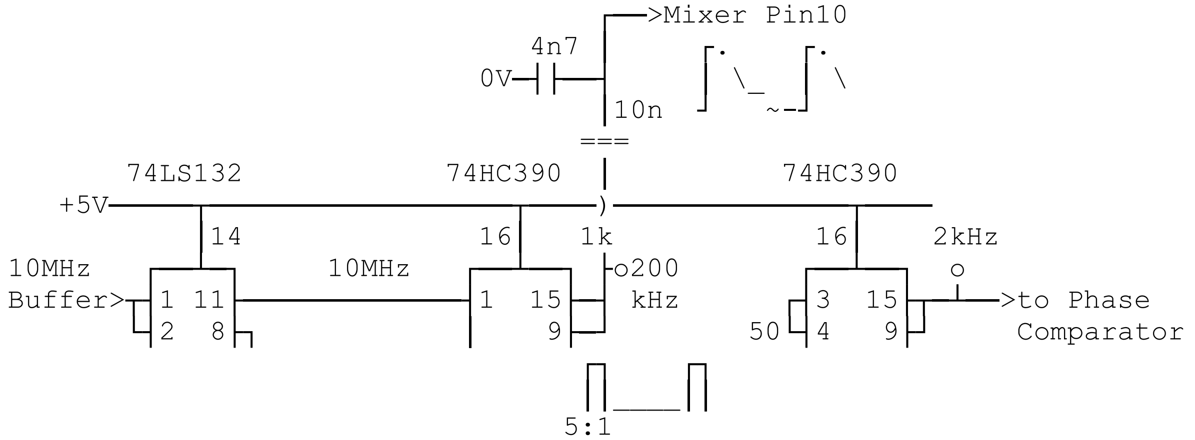


The two 100k Rs set the AGC gain & with the 10u sets the AGC time constant. It is fast enough to remove some of the AM components below 10Hz, but still give a stable AGC, leaving a fairly unmodulated carrier after the narrow IF filters have removed the higher frequency sidebands.

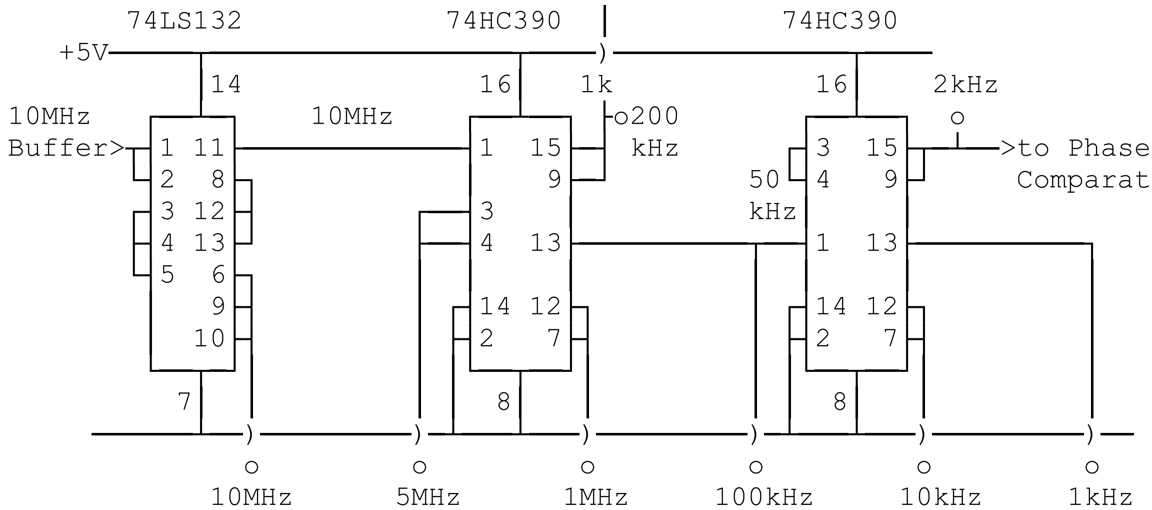
With the above modifications signal bandwidths down the Rx are now something like this..



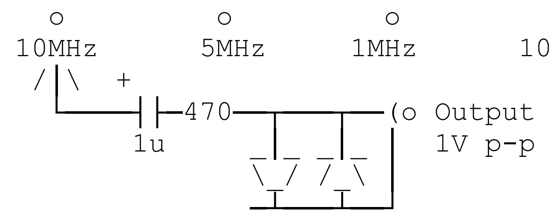
7/ LOCAL OSCILLATOR
The narrow 1:5 200kHz pulses fed to the mixer has been ramped a bit with an additional 4n7 & 1k (was 10k), this yields 3dB more mixer gain (ideally a 100mV square wave is best).



8/ OUTPUT FREQUENCIES
As my unit's dividers were not wired up as published, here is the arrangement.



9/ OUTPUT PROTECTION
By adding a pair of 1N4148 diodes as a clipped attenuator the TTL chips are protected from external static damage & small amounts of accidental RF (10W?).



10/ 12V POWERING
The original circuit was mains only to provide +12V & 5V rails from centre tapped 2x 6V transformer & single bridge to make 20V & 10V into their respective regulators etc. The +5V is used for PLL tunning & must be accurate, but the +12V is not so important, so I made a 12V input option to feed both regulators.

RESULT
I now have a very accurate marker for HF (VHF/UHF on harmonics with a steady pure tone), & I can calibrate frequency counters, or lock them up to this source, as well as lock up my 100Hz-1GHz PLL signal generator.

For VHF & UHF, Xtal oscillators age & can't be relied on to maintain high accuracy over several years. This accurate source (better than 1 in 10^7 shorterm & 1 in 10^11 longterm) enables checking of standards.

See my buls "Off Air Lock for Ref Osc.", "Comparing Off Air Freq Standards", "Simple Crystal Oven", "Crystal Drift Compensation" & "Calibrating Frequency" for more information.

Why Don't U send an interesting bul?

73 De John, G8MNY @ GB7CIP