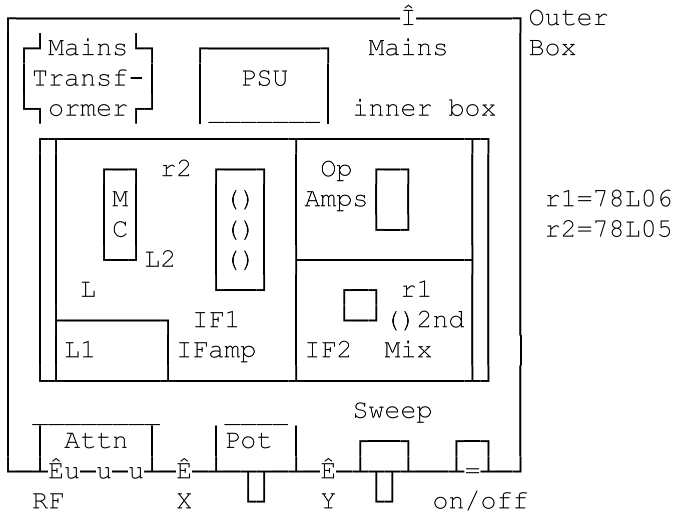
Spectrum Analyser mods 88-89

By G8MNY (Updated Mar 15)
(8 Bit ASCII graphics use code page 437 or 850, Terminal Font)

Here are 22 modifications I have done to the popular scope adaptor design that was first published in the RSGB's Radcom Technical Topics Apr 1988.

This design used just 3 ICs, 4 regulators & 1 transistor. A MC3356 is the 1st osc mixer & log IF (most of the 94 transistors in the IC are not used), a MC602 (NE602) 2nd osc mixer, a TL084 quad op amp to do the sweep, & ±12V 1A, +5 & +6V 100mA regs. (in 1989 a similar mark 2 design & PCB kit was published, with bells & whistles, very complex with loads of 741s & calibrated switches).

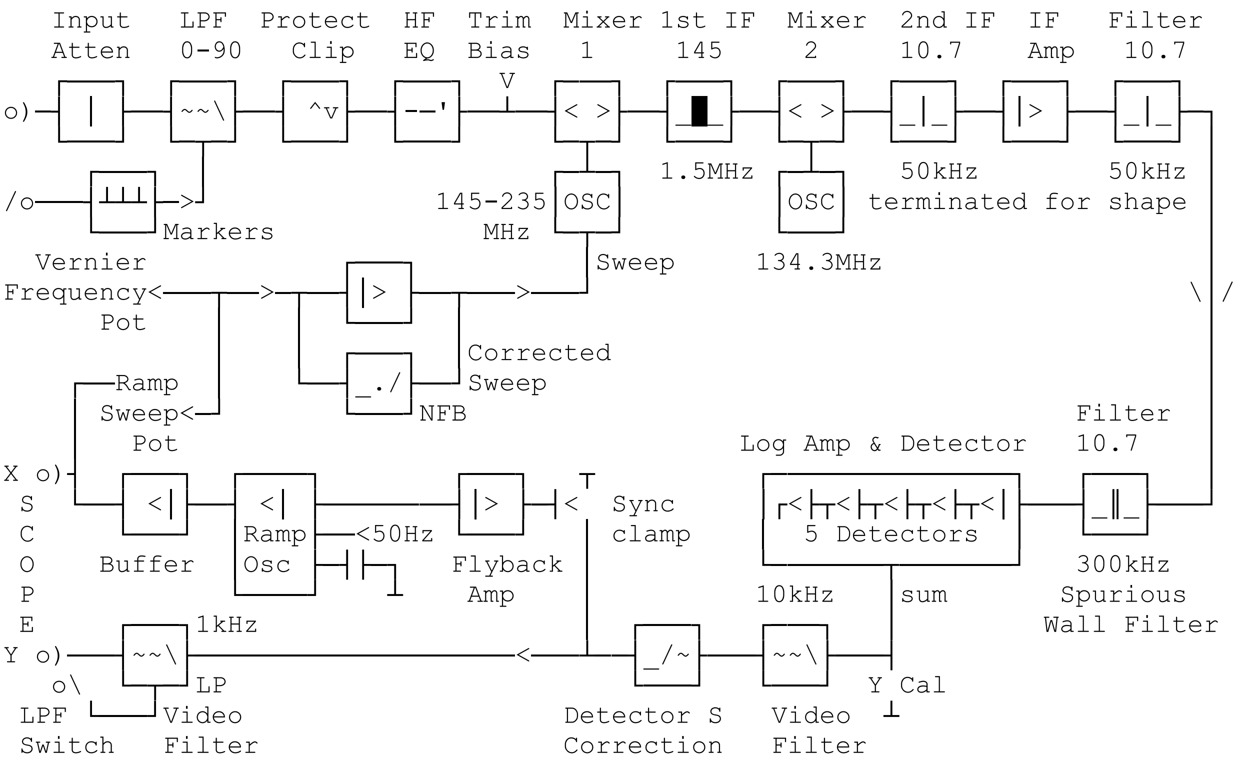
LAYOUT



My one was very neatly UGLY constructed (not by me) with double sided PCB made box & aluminium folded U top cover.

Then again with the RF bits in a 2nd bolted in PCB box with individual screen partitions & RF feed through caps for lines in & out, an RF tight fitting fingered aluminium lid.

MY IMPROVED DESIGN



After modifications here is the upgraded Specification:-

Frequency Range 200kHz-90MHz
Level flatness 200kHz-70MHz -3dB, 80 -6dB, 90-16dB

BNC 50Û input @ up to +20dBm (0.5W Max with all atten in),
70dB of input Attenuators 10, 20, & 40dB.
IF bandwidth 50kHz @ -20dB
Video Bandwidth 10kHz or 1kHz @ -3dB
Sensitivity +20dBuV (10uV) for 10dB/Noise
1st IC protected by clipper (not attenuator)

70dB of vertical Y log scale. (±2dB)
60dB mixer dynamic range before onset of mixer overload
BNC Y Scope output calibrated to 100mV/10dB, with negative flyback syncs.

Sweep rate 50Hz flyback locked to supply (±1Hz)
BNC X scope Ramp Output 20V P-P
5MHz RF Markers up to 90MHz
Vernier Dial Frequency readout, Accuracy ¾ 1MHz
No display of lower image sideband (below 0Hz)
210-254V 50-60Hz Mains Operation 10W.

CIRCUIT MODIFICATIONS:
INPUT
1/ There are 3 attenuators, the 10 & 20dB are accurately achievable with 1 double pole changeover switches separated by PCB screens. But the 40dB one is not so easy, & needs some attention to detail, & an additional screening plate between the connections to achieve it over the frequency range.
Note the 2k4 & 51Û are E24 series, but 2k2 & pairs of 100Û (* or 3x 150) work quite well & may give higher dissipation if 500mW is put in. All Rs small types & NOT WIRE WOUND! Very short leads are used on the 3 small switches.

```
        ┌───────────────┬───────────────┬───────────────┐
        │ ┌────2k4────┐ │               │               │
        │ │  o───────o │ │  o──────────o │  o──────────o │__ 50Û Coax
BNC  o)─┴─o/    |    \o┴─o/          \o──o/          \o─)__ to filter
Input   │    o┐ | ┌o     │  o┬─270Û─┬o   │  o┬─68Û─┬o    │
 50Û    │  * 51Û | 51Û   │  68Û    68Û   │ 100Û   100Û   │
        └─────┴──┴──┴────┴────┴──────┴───┴────┴─────┴────┘

              40dB           20dB            10dB
```

I found that the losses reduced by the odd dB at higher frequencies, this is due to.. switch crosstalk capacitance, series R capacitance or low Û R inductance, earth inductance etc.

2/ At the input to the low pass filter, add a 5MHz marker clock oscillator IC mounted right beside the filter L. The output is loosely coupled by stray capacitance with its short 1 cm lead for accurate frequency markers.
(The mk 2 SA has a marker already). The L1 is 5 turns wide spaced 5mm dia.
DC is via a push button.

```
Markers           14 ┌─────┐9   stray pick up   protection
 ─o\─┬─470Û──────────┤5MHz ├──────────────── L1    clipper          HF lift    Pin 20
+12V │         │   │ │ OSC │  from >─┬─(((()─┬─────┬───┬───┬─┤├─((((()──┬────> MC3356
    ===       _|_ ===│  IC │  atten  ├─┤├─┤       _|_ _|_  │ 10n 8turns |/\  250Û
   u1│    5V/_\'  |u1└┬───┬┘       === 15p ===  \_/ /_\ 62Û      6mm   ===   I/P Z
     │         │   │  │7 1│    56p │        56p│   │   │   │            /│  20p
  ───┴─────────┴───┴──┴───┴────────┴───────────┴───┴───┴───┴────────────┴──────
                       CLOCK IC            LPF    2x1N4148  Term
```

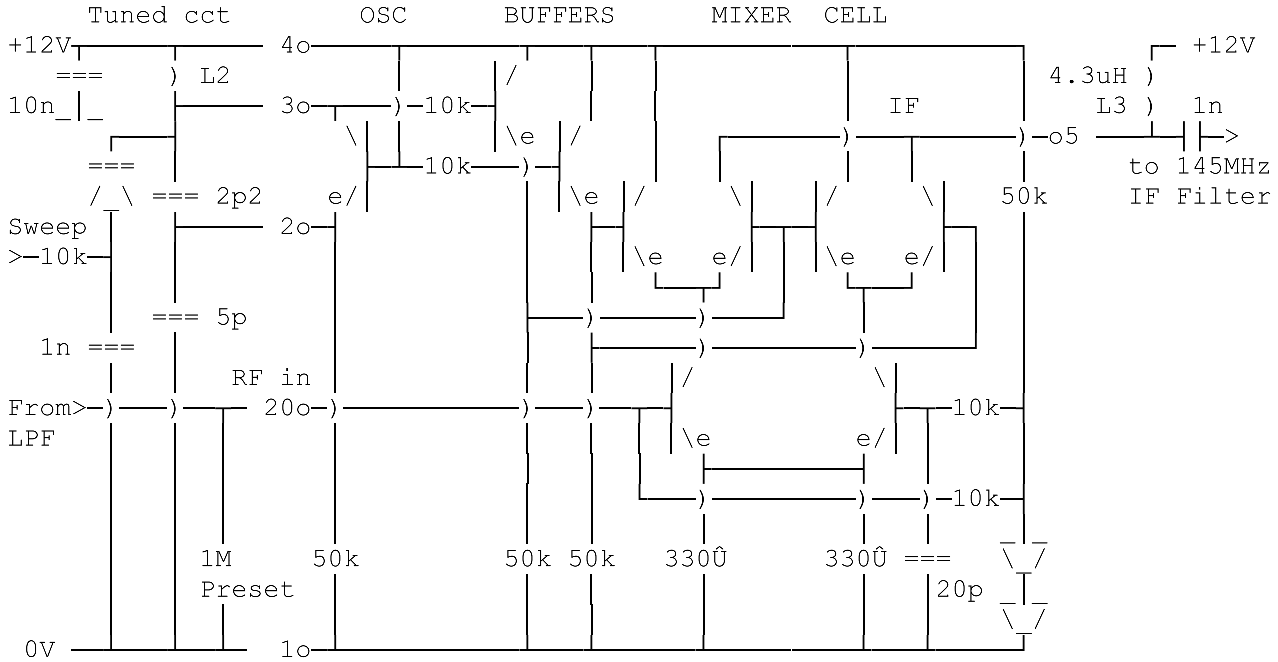
3/ Change the low pass filter termination to 62Û as it is in parallel with 250Û IC input Z. My filter is 3dB down @ 90MHz with about 30dB rejection above that.

4/ Add RF clipping diodes across termination R to protect IC1. These do not conduct at all, for on screen signal levels. But do stop you blowing up the IC with silly signals (e.g. from a handheld), but the input attenuator is unprotected!

5/ The conditioned signals from the attenuator & VHF wall filter is fed through an L & C trimmer for best HF level @ 70MHz into the 250Û input Z of the mixer IC1 (1st ½ of MC3356 IC). The IC is not designed for the Local Osc @ so high frequency, so there is some drop off @ 80MHz sensitivity without this tweak.

1st MIXER in MC3356.
A 2:1 step up ferrite transformer & no termination resistor will give 6dB more gain, but no transformer is flat over 0.5 - 90MHz range so this is not used. The mixer has a gain of about 5dB.

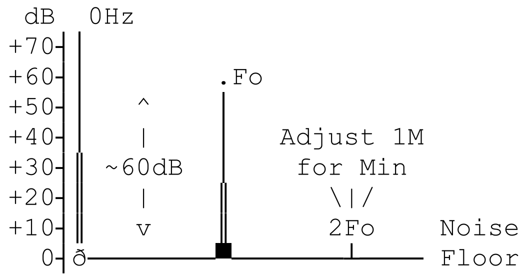
The osc provides 2 out of phase outputs (one with no RF!) that are buffered to drive the Gilbert mixer cell (unbalanced), which has one RF input & 1 output.



L2 is a spread out coil 5 turns 5mm dia. The 12V is well decoupled with 10n @ L3. The original Varicap was a MV209.

N.B. never accidentally put a earth on pin 2, as this will destroy the OSC NPN!

6/ To get the last drop of balance out the 1st mixer, I found a 1M preset from RF input to ground could give a slight improvement in balance & reduce a 2nd harmonic of a pure RF signal by 2dB.



If the balance is the other way, try the pot to +12V.

Use a well filtered Osc (2-30MHz) so the 2nd harmonic > -60dBc

7/ The varicap tuned first local VHF oscillator's range has extended to tune from 145MHz to 235MHz by adding further UHF Varicaps across the initial one & stretching/reducing the osc L2. This may depend on the varicap used & stray C.

8/ The local oscillator coil is adjusted to give 0Hz line (e.g. osc = 145MHz) when the FREQUENCY control vernier is set to 0 (mechanically near the -12V end of the pot, so that tuning sweep voltage after the amp is near to +12V). This also stops the unwanted image side of the 0Hz from being displayed & causing confusion. The 22uF bipolar cap removes any scratchyness in the freq pot.

```
+12V─────────────┐
           FREQ<──────────┬─────>Tuning
          10k POT         │        DC
                 │     ===22u
          80MHz CAL       │Bipolar
          5k PRESET      _|_
-12V───┤<├───────┘
      Thermal
    compensation. (See 21/ & 22/)
```

```
│        0Hz
│         │
│  No     │       5MHz
│Inverted │   │  Markers
│Display ║ │  │    │
│  \|/   ║ │ │ │ │ │ │
│________║_|_|_|_|_|_|_
```

1st IF FILTER
9/ Mine used a standard 50Û 2M three pole TOKO 144-146MHz filter, (the original article said to build your own). The TOKO one can be modified from a bandwidth of about 3MHz (-10dB) with 3 peaks, to a single peak 1.5MHz wide, by adding 2 small metal shielding strips (6mm x 8mm) to cover the 2 apertures between the 3 coil sections, BUT this is fiddly to do!

```
Underside view                      After mod
 ┌───┬───┬───┐                      ┌───┬───┬───┐
 │( ) ( ) ( )│                      │( )│( )│( )│
 └───┴───┴───┘                      └───┴───┴───┘
```

To see the 1st IF response on its own on the display, to tune it up, temporally remove connections to the 2nd IF filter & bypass it with a bridging 1nF cap & feed a carrier in (marker).

```
                                               ..
│      _   _   _                   │         /  \
│     / \./ \./ \                  │        |    |
│    |           |                 │       |      |
│   |             |                │      |        |
│  |               |               │     |          |
│_./      3MHz      \._            │____./  1.5MHz  \.__
└──────────────────────            └──────────────────────
```

Once the 1st IF's bandwidth is reduced then the number of signals reaching the 2nd mixer is greatly reduced & hence this reduces the amount of unwanted distortions & close in mixing products being displayed.

2nd MIXER.
This uses a NE602 osc & a balanced Gilbert cell mixer (used unbalanced) with similar internal circuit to that of the MC3356 RF part, it runs on its own +6V regulator & RF decoupled. Mixer gain is about 17dB.

```
+6V─┬───────┬──────────┬─────────┬──────┐    * see /11 for value
   ===   8t │,/\       │        *│     === 10n
 1n_|_  5mm (|         │8     430Û    _|_
          /(|   6      │         │
  134.3MHz├────┌─────────┐4       │        to 10.7MHz
     3p9 ===  7│   NE    ├─────────┴───────>ceramic
145MHz    ├────│   602   │                 filter
IF >──┤├───)───│         │                      N.B. as with 1st
     1n   │   1└─────────┘                      osc, an accidental
         ===      │2  │3 │5                     earth on pin 7 will
       6p8 │    1n=== │ ===1n                   destroy the osc NPN.
   ────────┴──────┴───┴──┴────────
```

10/ The VHF oscillator in the 602 should be run on a lower frequency (core "in" position) to the 1st IF, this is to reduce spurious images. e.g. 10.7MHz 2nd IF needs 134.3MHz, (or a 6MHz IF needs 139MHz). Due to the ferrite core this osc is susceptible to changes in magnetic fields, so mains transformer flux can be a problem for "zoomed in" stability!

2nd IF FILTER

11/ The 2nd mixer's output has in internal pull up of 1k5 to so get 330Û source impedance for the filter a 430Û on pin 4 determines the 2nd IF filter source impedance. (This is not applicable to the Mark 2 with narrow filter option)

```
│     .────.           │       .──.
│    Ì      ¦          │      /    \
│    ¦ COMMS Ì         │     |      |
│   |  Filter |        │    |        |
│_./   50kHz   \._     │_./           \._
└──────────────────    └──────────────────
 Correctly terminated     Mis Terminated
    RINGY FILTER       sweep friendly filter
```

If the filters are deliberately mismatched then they can give a better analyser friendly "rounded peak response" rather than the flat topped ringy edges of communication filters.

To find the best values for your filters use small 1k presets to source & terminate the filters to see this effect on the display of a carrier, find the optimum value for best IF shape & then replace the presets with nearest fixed values.

```
              +12V─┬─────────┬─────────┐
                  === u1     │   IF    │
          +6V     _│_       │   AMP  470Û
2nd  Pin 8<─┤            220k      ┌───┤
Mixer      430Û             │    │/    │
602  Pin 4>─┤      ┌────────┴────┤ T1  │
     Pin     _│_ _│_     BFX90│\e    _│_ _│_  _│_ _│_ 330Û             ┌──────────>Pin 7  To
      3     ┌─────┐              │    ┌─────┐   ┌─────┐  ├──────────>Pin 9  Log
      │ 50kHz└─────┘          100Û   └─────┘   └─────┘  └─┤├┬──>Pin 8  Detector
      │ 10.7 ───┬───         Preset ───┬───    ───┬───        ===
  ────┴─────────┴──────────────┴───────┴─────────┴────────────┴──>Pin 19
         1st filter                   2nd     Wide filter
```

Adjust the 100Û gain preset for the optimum noise floor that can just be seen.

12/ Adding an inter filter buffer stage using a single transistor T1 adds some preset gain for setting the overall noise floor of the analyser, as well as matching into a 2nd filter. This filter is terminated by the input load on the detector 330Û. Two 50kHz 10.7MHz ceramic filters provide a reasonable compromise of selectivity for sweeping 0-80MHz @ 50Hz without too much ringing distorting & loss of the peaks levels (up to 10dB) while still looking good in close "zoomed in" sweeps. However a 3rd filter was put in tandem with the 2nd filter to clean up poor filter skirt rejection of my particular narrow filters @ 7MHz!

LOG DETECTOR

13/ The detector (S meter output) uses 5 IF amps & detectors (with limiters) to obtain log response & it is quite accurate for over 40dB range. But ignoring the slight overload in the mixers this range can be extended on the display, by increasing the gain calibration preset (1k preset now 2k2), & then adding a non linear correction attenuator with diodes D1 (Schotky/Ge) & D2 (Si) to give 30% stretch @ the highest & lowest levels where the detector has lower sensitivity.

```
                           Ge                            1.0 ┤Output from          _.-'
MC3356  pin           ┌──┤>├──┐          Y to         .9 ┤Detector          .-'
LOG     14>───────────┼───────┼──────────> scope      .8 ┤                .'
DETECTOR          │   ├─10k───┤       │               .7 ┤              .'
          2n2     680Û         │       │  T2           .6 ┤            .'    S
     Video ===     │     22k      \│   Timebase        .5 ┤          .'  Correction
     Filter │   2k2     _│_       │──<Sync/           .4 ┤      _.-'
            │   Y CAL \_/Si e/│   Blanking            .3 ┤_.-'
Pin 11>──┤├─┴────┴──┬───┴───────┴──────────            .2 ┤
Lim out  1n        _│_                                 .1 ┤                          Display
is RF                                                  0v ┼──┬──┬──┬──┬──┬──┬──┬──┬>output
grounded                                                   0  10 20 30 40 50 60 70 dB
```

With this correction you can get good display linearity to 70dB. Easily tested with input attenuator & a signal generator to see equal height 10dB steps.

14/ The sensitivity is set by the Y Calibration preset to give 100mV/10dB. A 2.2nF capacitor limits the Y video bandwidth to about 10kHz (50%), but having hardly any degradation of pulse height at the widest sweep range.

VIDEO FILTER

15/ For some applications lower video bandwidth is needed to reduce noise, I added a 33nF switched across the Y output incorporated with the above mod, to give about 1kHz Y bandwidth (50%).

```
─10k──────┬──>Y to
          │    scope
  o\──┤├──┘
 _│_  33nF
```

It needs to be switchable as it causes the output to lie about the fine detail with wide sweeps.

POWER SUPPLY

16/ The hot +12V regulator has been heatsinked, & the + rail input smoothing capacitor increased from 680uF to 2m2. Transformer & rectifier pulse currents wiring & layout have been kept away from the regulators as far as possible to reduce supply hum ripple pickup.

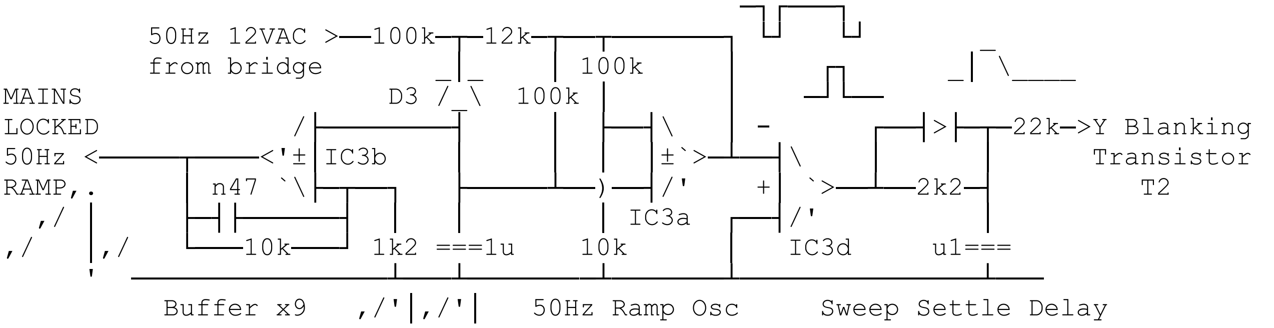
```
                                       Heatsink
                 4x 1N4001      +17V   ┌────┐
                ┌───────┤>├──────┬─────┤7812├──┬─────────> +12V    Much larger output
 L >─o/ o──┐   │   _│_   _│_   2m2 │+    └─┬──┘ +│330u      200mA   caps have been
      100k )║(   /_\   /_\   25v===        │    ===16v             used to reduce
240V       │ )║(___ │ ___ │  ______│_______│_____│______\ 0V      the last remnants
     NEON )║(      │     │   680u│+         │     │+    /           of hum & noise.
           │ )║(      │     │   25v===       │    ===330u           This is most
 N >───────┘ ║(      └─────┼────)─────────┐  │      16v             important
             ║ └────────┬──┴───┤<├──────┤┌─┴──┐│                   for close in
 E >──┬──────┘           │              └┤7912├┴────────> -12V     stability.
      └─> 0V    14-0-14  │       -19V     └────┘          20mA
                0.3A     └─>50Hz
```

The mains transformer has also been varnished to reduce acoustic hum & an outer copper short circuit added to reduce magnetic fields that can affect the 2nd osc stability. The other 2 low power regulators +6V for 2nd osc, & +5V for Log amp, are placed near those circuits for best noise/voltage error rejection.

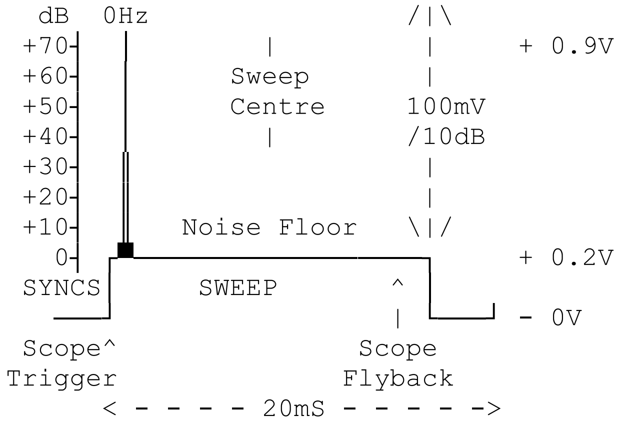
17/ A 50Hz synchronisation line is provided for ramp timebase locking. This is important for close "zoomed in" stability of the sweep.

RAMP GENERATOR
In the simple mark 1 design, it uses 4 operational amplifiers IC3 (e.g. TL084) that run on the ±12V. The original circuit produced a symmetrical 500Hz ramp up & down oscillator which was far too fast for wide sweeps & half the time was wasted during the flyback. Mod 18/ solves this.

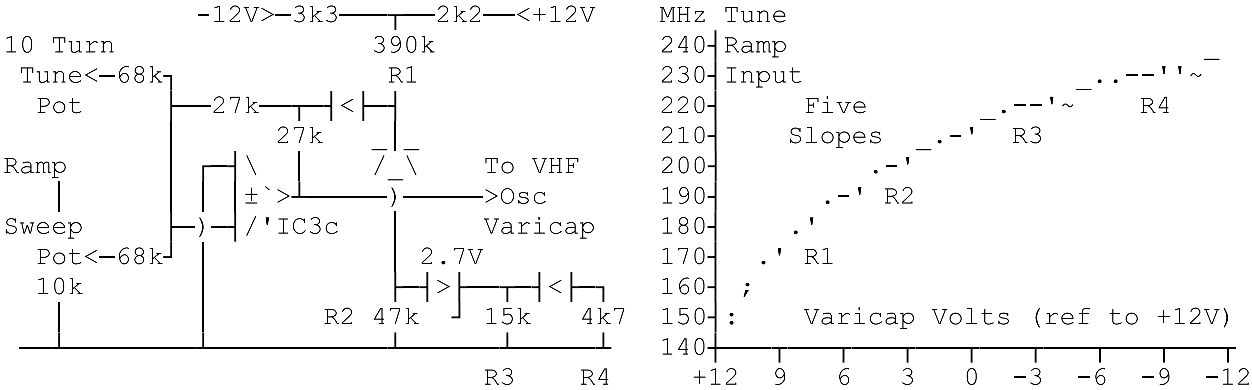
18/ IC3a forms a 50Hz ramp oscillator with the 100k & 12k in parallel during flyback due to the diode D3, & a 1uF timing capacitor to give close to mains frequency. Then a small injection of 50Hz from the mains transformer alters the flyback time (D3, 12k & 1uF) to cause lock up to mains frequency. This method ensures constant sweep MHz rate & the mains lock ensure a stable display even with some sweep hum present when zoomed close in.



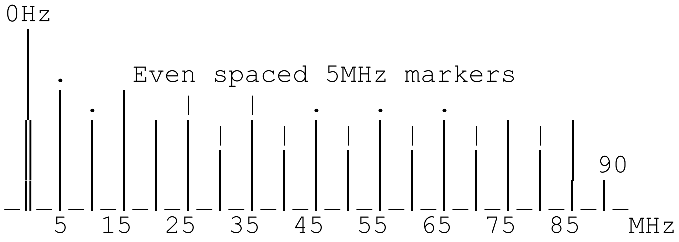
19/ IC3d buffers & inverts the banking pulse & it is lengthened with CR & a diode before it drives blanking transistor T2. This eliminates any sweep folding due to VHF osc sweep settling delay with RF sweep filtering to be masked. And the banking also gives the scope a 0V sync pulse to lock to.



20/ IC3c is the sweep correction amplifier, this amplifies the selected sweep width together with the centre frequency DC, then corrects for VHF oscillator varicap frequency control non linearity by pre-distorting the ramp waveform with 5 gain changes using 4 diodes, D4-D6 & ZD2 zener.

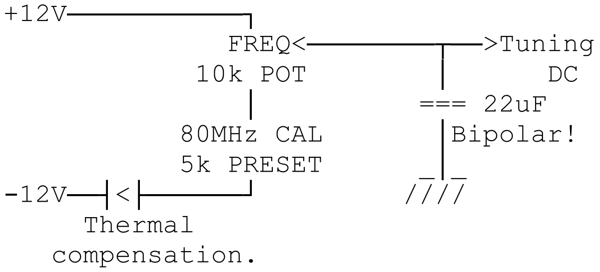


The R1-4 values used for the gain corrections are set up using the marker to give even spacings on the display.



FREQUENCY CONTROL

21/



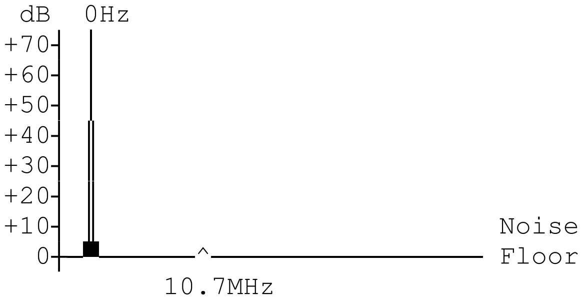
The multiturn vernier centre frequency control has a 22uF bipolar capacitor to ground (or elect to +12V near the ICs) to remove any pot scratchiness.

22/ A multiturn preset pot on the positive rail of the control is added to calibrate 80MHz position on the vernier scale. A diode in series gives some temperature drift compensation. Together with the correction circuit of IC3c fairly accurate frequency readouts are possible on the vernier scale. 0-90MHz.

I N U S E

IMAGES

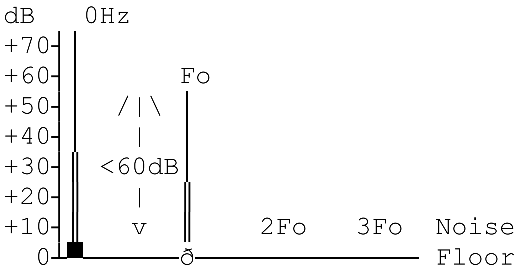
Other than the 0 Hz line, there is only one unwanted image @ 10.7MHz, it is at a low level & its appearance depends on the IF gain setting. It is due to the second IF detector being in the same IC as the RF input section!



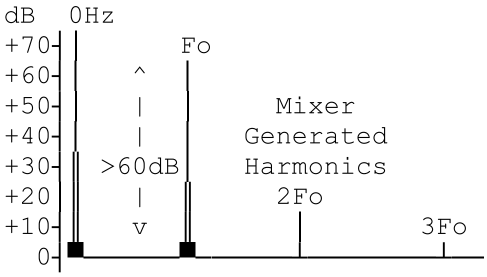
VHF images are all well down due to the VHF LPF & the chip sensitivity cutting off as well as the input filter & double screened box.

OVERLOADS

These can be seen as higher levels of harmonics increasing at a greater rate than the fundamental. e.g. a 10dB increase in level, causes the fundamental to increase by 10dB (1 division), but the 2nd harmonic increases by 15 to 30dB!



Filtered Osc test



Filtered Osc test
OVER LOADING 1st MIXER

They can also be detected as unwanted sidebands around the markers too.

```
 dB                                      dB
+70┤      Signal                        +70┤
+60┤        │                           +60┤
+50┤        │                           +50┤
+40┤        │   Marker                  +40┤
+30┤        ║     │                     +30┤  Base Noise Floor
+20┤  S─M   ║     │      S+M            +20│     Raised        __
+10┤  Mix   ║     │      Mix            +10┤       __..--""~~
  0┤──┴─────█─────ð──────┴──────          0┤──""~~
   POSSIBLY OVER LOADING MIXER               GROSS OVERLOAD
```

Other signs of overload is a raised noise floor.

CLOSE IN OVERLOADS
These are much the same as above, but occur when the 2nd mixer sees 2 large signals passing through the 1st IF filter. So if the narrowing of that filter has been done, strong signals will need to be closer than 1 MHz to suffer this problem. (e.g. using the analyser closer than 1 MHz from 0 Hz reduces dynamic range due to the increased noise floor from its' own 2 oscillators)

FILTER NOISE SIDEBANDS

```
 dB                                              With large carriers are looked
+70┤                                             at close in, you will see noise
+60┤                /~\                          sidebands (phase noise) added
+50┤               │   │                         to the filter response, this is
+40┤               ¦   Ì                         normal for this sort of analyser.
+30┤              Ì     ¦
+20┤ Sideband    █¦     Ì█   Sideband            Lower frequency Y display filtering
+10┤ Noise     ██         ██    Noise            can mask this, but at the cost of
  0┤─────╛███   <50kHz>    ███╘──────            peak pulse height accuracy.
```

SWEEP NOISE
Some of this phase noise can be noisy sweep amps, as the S/N needed on the VHF osc will be >120dB, e.g. 24V max sweep & < 24uV of noise! I have used active sweep filtering on some analysers to overcome this failing where the sweep rate is low & a CR filter after the last opamp does reduce the HF noise sent to the oscillator.

```
         ┌─┤>├─┐              The diode direction (depends on circuit)
   │\    │     │              ensures the flyback charges up the cap
 OP│ `>──┴──R──┴─┬────>VHF OSC voltage quickly, so there is little cramping
amp│/'          === C        at the start of the sweep.
               ──┴──        e.g. Xc = R (-3dB) @ 10x sweep freq.
```

Why don't U send an interesting bul?

73 de John G8MNY @ GB7CIP