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A Spectrum Analyser for the Radio Amateur Part 2 – Concluding

5. THE FIRST LOCAL OSCILLATOR

This oscillator, tuning from 450 MHz to 1000 MHz, has already been described in VHF Communications 4/86 and therefore the details here can be

held to a minimum. In this version, shown in **fig. 5.1.**, the oscillator transistor is a BFR 91 and the buffer amplifier an NPN transistor BFG 96, the latter delivering at least 10 mW drive to the following SRA 220 ring mixer. An auxiliary buffer output of 0.5 mW is taken from the twin-hole cored transformer and used for the tuning linearity circuits and for the PLL drive. The components are soldered to the track side of the printed circuit board, the arrangement being shown in **fig. 5.2.**

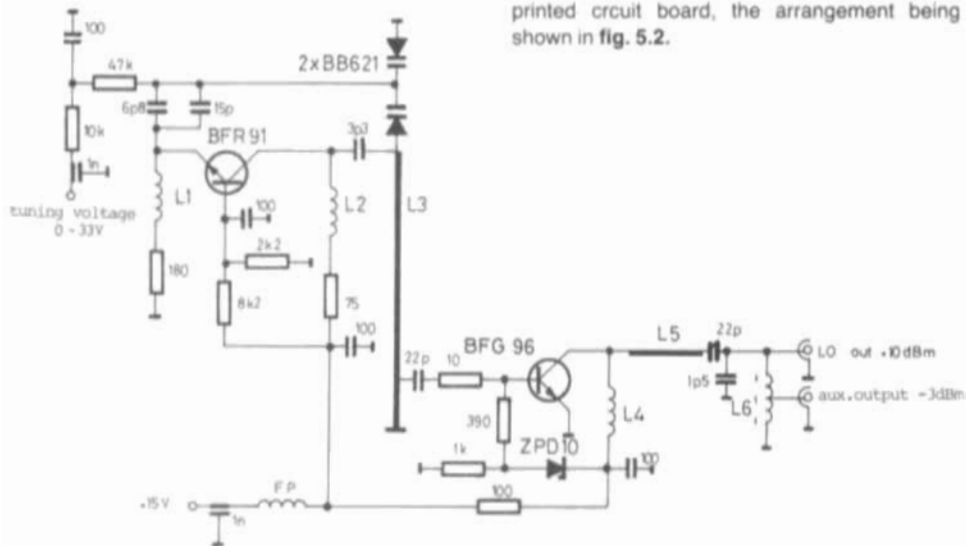


Fig. 5.1.: The first local oscillator having a 450 MHz to 1000 MHz tuning range

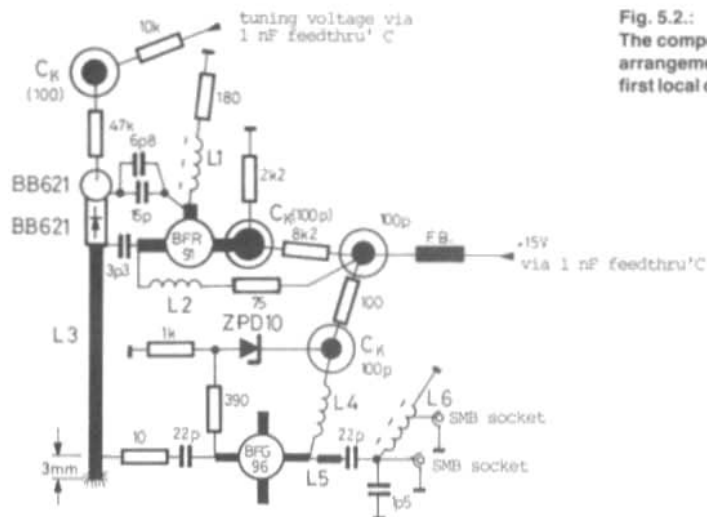


Fig. 5.2:
The component
arrangement of the
first local oscillator

6. FREQUENCY CONTROL LOOP AND TUNING LINEARITY

The relationship between the tuning voltage and the output frequency of a diode-tuned oscillator normally approximates a square root function. In order to obtain a linear relationship between tuning voltage and frequency, it is necessary to employ a resistance-diode network possessing an inverse characteristic, which, when combined

with the VCO characteristic, produces the desired linear relationship. The only snag with this arrangement is that each oscillator must be individually adjusted for optimum results.

The employment of a frequency control loop is an alternative method of obtaining the linear relationship between tuning voltage and VCO frequency. A highly linear discriminator is fed from the output of the VCO and delivers information concerning the actual frequency of the VCO. A control amplifier then causes the VCO to return to the set frequency. The disadvantage of this

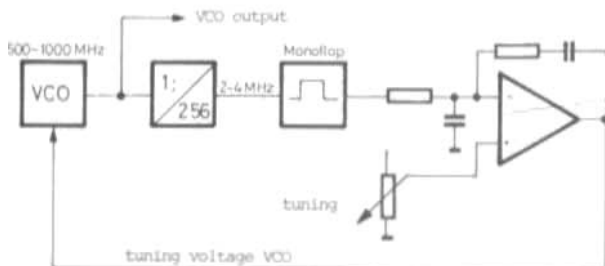


Fig. 6.1:
Frequency control loop
used to linearise the 1st
LO's tuning characteristic

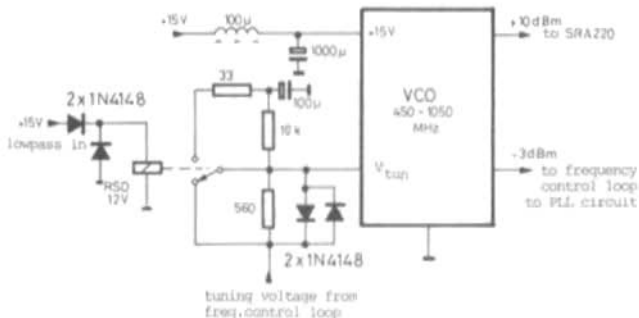


Fig. 6.3.:
The external circuitry of the
1st LO

0 – 30 V and an LC network filters out the residual RF.

Immediately before being applied to the VCO control input, the tuning voltage may be additionally filtered by a relay selected RC network (fig. 6.3.). This extra filtering, although improving the noise superimposed on the control voltage, also increases the control loop reaction-time enormously. For this reason it is only activated when the spectrum analyser is being swept at narrow band (200 kHz/div.) from the 2nd local oscillator. The detail is shown in fig. 6.3. The reference frequency for the loop is represented by a weighted sum of the tuning potentiometer voltage, the sweep voltage and the tuning voltage from the PLL circuitry. A second NE 5534 is used here as the summing amplifier. Two multi-turn trimmers adjust the centre frequency and tuning sensitivity.

With the dimensioning as suggested here, the frequency control loop has a 200 Hz bandwidth. This allows a loop reaction time to tuning voltage variations of 1.5 ms. The VCO frequency stability is better than 100 kHz with this control loop and it is, in most cases, largely dependent upon the externally generated tuning voltage.

A static measurement of linearity using a frequency counter and a digital voltmeter reveals practically no errors. The VCO exhibits a residual

modulation, i. e. from hum and LF noise, of some 30 kHz peak. Only on the filter bandwidth from 1 to 2 kHz can it be observed that a better VCO stability would be desirable. This theme is pursued in the following chapter which introduces a PLL circuit which may be switched to sweep presentations of 200 kHz / div. or less.

7. THE PHASE LOCKED LOOP

When swept displays of under 200 kHz / div. are required, the spectrum analyser presented here sweeps the 2nd LO at 460 MHz whilst the 1st LO is free-running. In order to reduce the effects of the 1st LO's noise modulation, the oscillator is controlled from a crystal frequency reference. The author attempted to use a television receiver PLL synthesizer for this purpose but it proved unsuitable. Test measurements showed that the noise from a television synthesizer was greater than that from the frequency control loop described above. The trouble lies in the large division factor of 64 or 256 in the TV tuner and its inherently low phase comparator frequency.

The PLL circuit is therefore so dimensioned that the smallest possible VCO division factor is used.

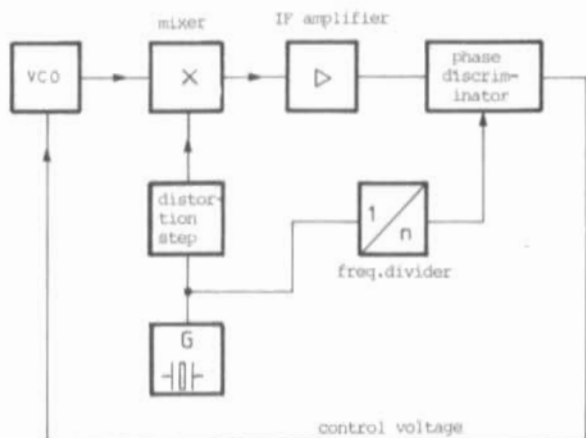


Fig. 7.1:
1st LO PLL block diagram

In the interests of easier operation, a control technique, which allows manual tuning between fixed spot frequencies, is to be preferred. One possibility is a PLL circuit with harmonic mixing as shown in block diagram (fig. 7.1.). The VCO signal is mixed with a harmonic-rich crystal oscillator. The resulting intermediate frequency is amplified and taken to a phase / frequency comparator which controls the VCO tuning voltage.

A problem crops up here with the production of the harmonic signals as the spectrum must extend well over the 1 GHz region. The author found that an harmonic spectrum up to about 300 MHz could be achieved relatively easily by using the gate times of TTL circuits. This offers the possibility of dividing the VCO frequency to under 300 MHz and then to arrange the harmonic mixing.

The final PLL circuit is shown in fig. 7.2. It may be seen that the input again possesses a resistive divider which passes the greater proportion of the input power to the LO output on the front panel. A smaller portion is amplified by a two-stage transistor (BFR 15) amplifier and taken to the CA 3199 ECL scaler.

The price of integrated UHF circuits has fallen recently (to less than 10 DM) making their use almost mandatory. For a start, the Mini-Circuits MAR-8 is suggested. The input signal is divided

by 4 in a reasonable priced (6 DM) CA 3199 frequency scaler which is capable of working up to 1250 MHz. The output from the divider is taken via a low-pass filter to a mixer which is arranged in a sample-hold FET circuit.

A CD 4060 crystal oscillator circuit working at 4 MHz is divided by 16 and presents a 256 kHz square wave into positive going needle pulses about 2 ns wide. The needle pulses gate the FET switch. A further division of the crystal frequency produces a 32 kHz reference for the frequency / phase comparator.

The IF signal is taken at high impedance from the mixer by a FET buffer and then on to the CD 4046 frequency / phase comparator via a 50 kHz low-pass filter. A control voltage from the CD 4046 pin 13, is eventually taken to the PLL after being filtered and buffered. A BF 246 FET switch passes the PLL control voltage on to the phase-lock input of the frequency control loop (fig. 6.2.). The 500 Ω preset is adjusted to optimise the PLL sensitivity. A lock-detect signal is also available from the CD 4046 pin 1. This is made to drive an LED located on the front panel, marked "LOCK", and signals the correct functioning of the PLL.

When initially switched on, it was found that the PLL did not lock at or near the selected spot fre-

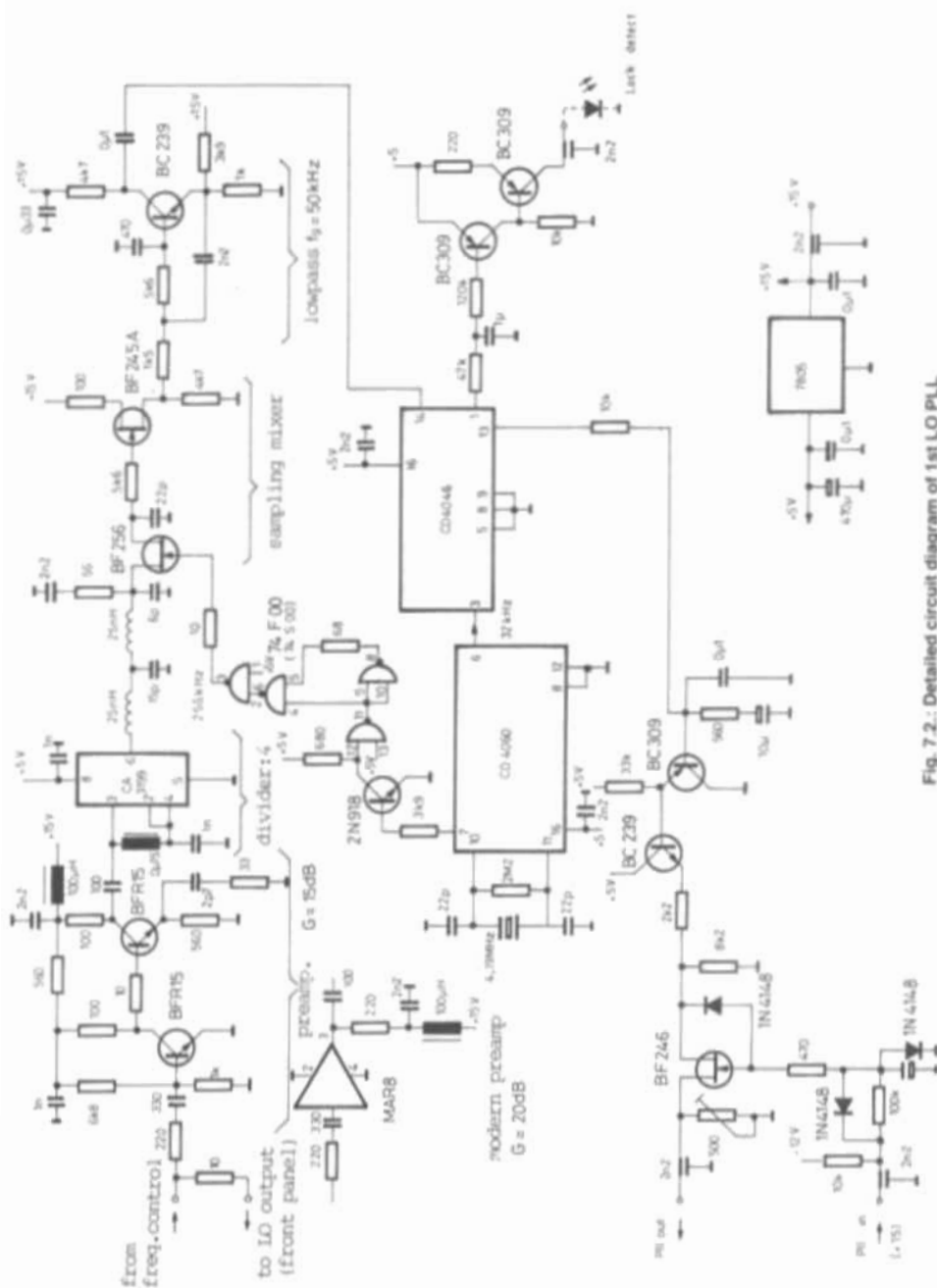


Fig. 7.2.: Detailed circuit diagram of 1st LO PLL

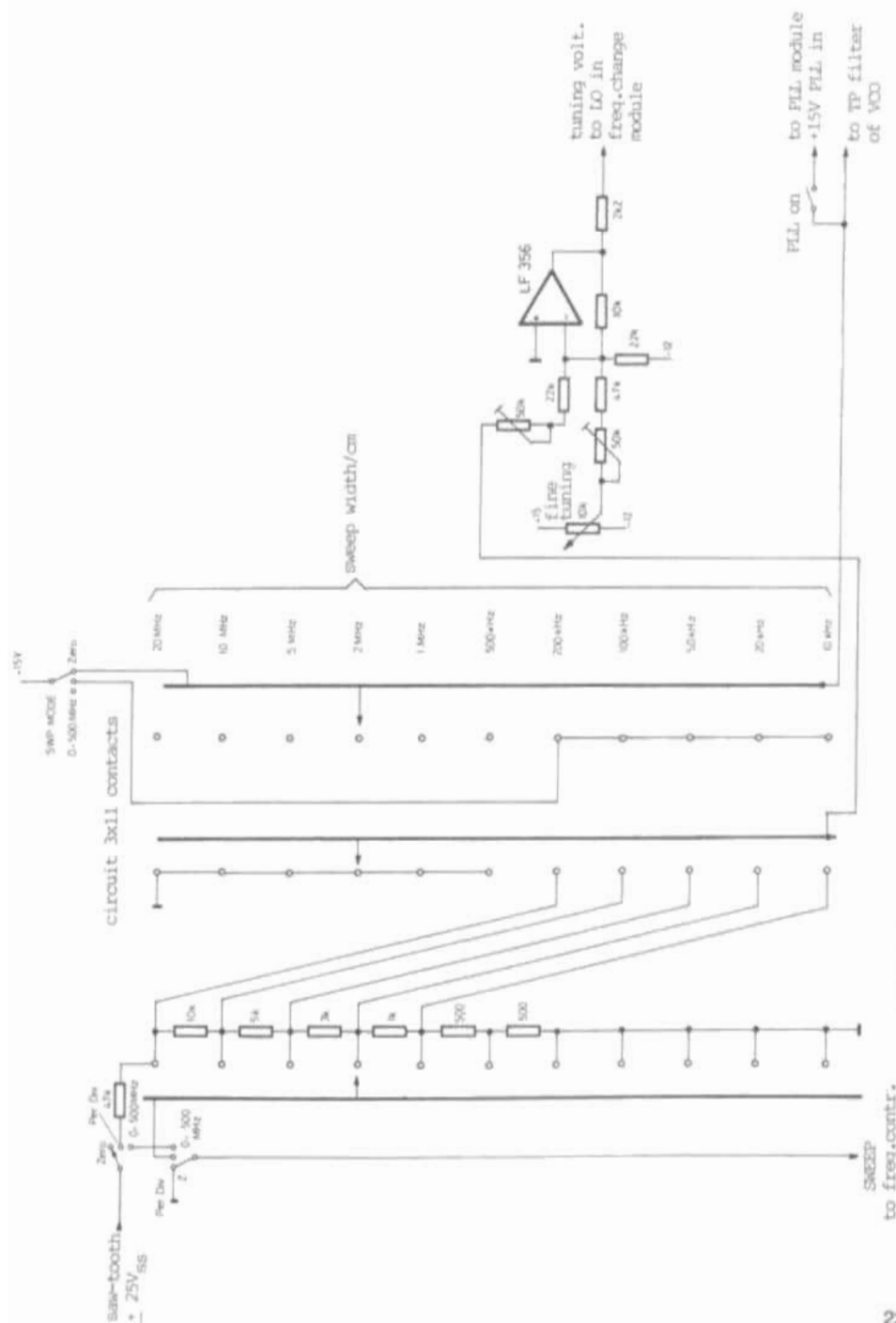


Fig. 8.2.: The switching logic for the tuning voltages of the 1st and 2nd LOs



The circuit details to be considered now are the production of the tuning-voltage supply, the digital frequency indicator and the support module for the display sweep-width. A 100 k Ω , 10-turn potentiometer serves as the tuning potentiometer. The tuning voltage, in the author's version was drawn from a highly stable ± 100 V supply which was available in the instrument. This voltage range is not strictly necessary as the tuning range can be altered by suitable dimensioning of the summing resistors in the frequency control loop circuit to suit the available tuning voltage supply to the tuning potentiometer. The main thing to watch, is that the supply itself is absolutely stable and free of hum and noise.

A digital voltmeter can be used as the frequency display which is actually measuring the tuning voltage. The author used a 3 1/2 digit voltmeter with an LCD display and a 2 volt range. This used the well-known CMOS module ICL 7106 or ICL 7116 by GE-Intersil. This unit is equipped with a floating differential indicator and has a consumption of only 2 mA! As opposed to the usual 9 V battery supply, a mains derived source is used in a full-wave circuit to two Z-diodes delivering ± 4.7 V w.r.t. ground.

When constructing this item, or using a modified commercial digital voltmeter, two points should be considered. If the module originally used 9 V batteries then the minus (pin 30) is strapped to ground (pin 32). This connection is to be interrupted.

This IC sometimes exhibits problems with common-mode voltages which drive the integrator into a premature run-down condition. This has the effect of the display indicating up to a certain input voltage and then saturates, or sticks, at that indication. This effect can be countered by increasing the value of the integration resistance at pin 28 or increasing the value of the integration capacitor at pin 27.

Figure 8.1. shows the external circuitry used by the author to support the ICL 7116 in the area of the signal input. By means of a selector switch, either one of two receive input ranges may be selected 0 to 500 MHz or 1000 to 1500 MHz and correctly indicated. Operating this switch can also be caused to switch in the appropriate high

and low-pass filters before the first mixer, but the author did 'nt do it in this manner in the prototype instrument. The frequency indication has an accuracy of a few MHz which is sufficient for most purposes. If a higher accuracy is desired, it can be calibrated with a spectrum generator.

The sweep voltage, employed to wobble the oscillators of the spectrum analyser, is a symmetrical about zero, saw-toothed wave-form of 25 V peak to peak. The frequency of the wave-form is variable between 2 Hz and 25 Hz. The generation of the various scan widths is given in **fig. 8.2.** By means of a stepped divider sweep widths of 10 kHz/div. and 20 MHz/div., in a 1-2-5 sequence, may be selected. For scan widths over 500 kHz/div., the 1st oscillator is deviated with an attenuated portion of the sweep voltage applied to the frequency control loop circuit. When smaller scan widths are selected, only the second oscillator is wobbled. Also, the sweep-voltage and the voltage from the fine-tune potentiometer are summed in an operational amplifier and taken to the 2nd LO's varicap diodes in the IF converter module. A correction of the tuning characteristic was found to be unnecessary. In this mode of operation, the control speed of the frequency regulator loop is reduced in order to attenuate the 1st LO's noise modulation. In addition, the PLL stabilization can be switched in.

By means of a further switch a display over the whole 500 MHz range can be selected – the mid-frequency being fixed. Another facility is that the whole wobblelation system can be switched off in order to observe the modulation on a single signal.

9. CONSTRUCTIONAL HINTS

There are many and various ways by which the described modules may be connected together to form a complete spectrum analyser. The most elaborate way is to make the display and power supplies in order to build a self-contained instrument. Life is also made easier when a ready-to-hand oscilloscope can be pressed into service



for the display. The oscilloscope's time-base can then be used for the spectrum analyser's saw-tooth waveform requirement. Most oscilloscopes have an external connector for the time-base voltage but if not, one can be easily fitted. Also, with any luck, the oscilloscope's power supplies will also supply the analyser's power requirements as well.

The owners of an oscilloscope having a plug-in unit capability are even better off. One of the plug-in units can be stripped and the chassis used to build the spectrum analyser circuits. The oscilloscope can then be used for its original purpose, or for the spectrum analyser facility, as desired. The author chose this method using a Hewlett Packard 140 A oscilloscope main frame and one of the little used plug-in options being turned into an analyser plug-in. The main frame could deliver + 250 V, + 100 V, - 12 V and - 100 V. The + 35 V and - 24 V supplies required by the analyser were easily derived from the +/- 100 V oscilloscope supply, using resistors and zener diodes.

The + 15 V supply had, however, to be a little more elaborate because of the 500 mA consump-

tion. One possibility, offered by all older plug-in oscilloscopes, is the employment of the 6.3 VAC heater voltage which is brought out at the main plug for the plug-in unit. Using a small laminated transformer, a full-wave rectifier and a three-terminal regulator, the necessary voltage may be made available.

The HP 140 does not have a deflection amplifier, i.e. the deflection card of the CRT lies directly at the plug-in's plug. Two deflection amplifiers are necessary therefore but the bandwidth need only be about 50 kHz. The author used for this purpose a ready-to-hand board which also contained a saw-tooth generator and a blanking amplifier which suppressed the trace return.

It is not necessary to go into further details as they are largely dependent upon the type of display device used by the author. Other equipment must use an individual method for utilising it to combine with a home-made spectrum analyser. Before attempting to modify an oscilloscope for this purpose, it is recommended that the oscilloscope handbook is given a thorough perusal. Details on deflection amplifiers may be found in



Fig. 9.1.:
The author's
spectrum
analyser



volume 4 of the series "Professional Electronics" published by Francis Verlag.

The author's prototype instrument is shown in fig. 9.1.

10. ADDITIONS

The spectrum analyser as described may be given a few further facilities. A few suggestions are given as follows:

– An additional VCO tuning from 1000 MHz to 1500 MHz will enable the input range to be extended from 500 MHz to 1000 MHz. The ECL divider, in the frequency control loop and in the PLL, are well able to work at these frequencies as tests have shown.

– A frequency converter or an external harmonic mixer for the microwave bands can be connected.

– A sweep generator having a 60 dB dynamic range and a tuning range of 0 – 500 MHz may be made by synchronising another oscillator so that it is swept in step with the spectrum analyser's 1st LO.

– Using high and low-pass filters, automatically switched with the input range switch, reduces the possibility of receiving spurious signals in the display trace.

– The use of a better, i.e. noise reduced, local oscillator will improve the instrument's dynamic range. This is extremely important when observing a number of closely arrayed signals with large level differences between them.

It may be seen that the spectrum analyser offers many possibilities for individual expansion schemes and for experimentation for improved performance with the basic circuits. The purpose of this article, as stated at the start, was to generate the necessary interest to begin a project of this kind and also to dispel the unfounded fears attending its complexity.

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