Maintenance manual

9009
AM/FM Modulation Meter

RACAL
THE ELECTRONICS GROUP

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Modulation Meter 9009

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HANDBOOK AMENDMENTS

Amendments to this handbook (if any), which are on coloured paper for ease of identification, will be found at the rear of the book. The action called for by the amendments should be carried out by hand as soon as possible.

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SECTION 1

TECHNICAL SPECIFICATION

TECHNICAL SPECIFICATION

1. INPUT CHARACTERISTICS

Carrier frequency range (Automatic operation)	30MHz to 1500MHz. Automatic measurements can also be made in the bands 10MHz to 13MHz and 20MHz to 26.5MHz.
Carrier frequency range (Manual tuning)	6MHz to 1500MHz using external local oscillator with a range of 13 - 28MHz. Input required 200mV to 1V r.m.s. into 50Ω.
Input level	Low input: 10 - 100mV r.m.s. to 500MHz. 20 - 150mV r.m.s. from 500MHz to 1GHz. 50 - 150mV r.m.s. from 1GHz to 1.5GHz (temp range above 1.25GHz 10° C - 30° C). High input: 100mV - 1V r.m.s. to 500MHz. 150mV - 1V r.m.s. from 500MHz to 1GHz.
Level setting	Fully automatic.
Input impedance	50Ω nominal.

2. FM MEASUREMENT

Deviation ranges	1.5, 3, 5, 10, 15, 30, 50 and 100kHz peak deviation f.s.d. Measurements of positive and negative deviations can be made.
Modulation frequency	50Hz to 10kHz.
Accuracy	Better than ± 3% of f.s.d. and ± 2% of reading over the modulating frequency range 300Hz to 3kHz; ± 0.5dB with respect to the above over the modulating frequency range 50Hz to 10kHz.
Residual f.m. noise	Without filter: less than 100Hz for carrier frequencies up to 250MHz then doubling per octave. With a.f. filter: less than 30Hz for carrier frequencies up to 250MHz then doubling per octave.
A.M. rejection	Additional deviation error is less than 250Hz with an a.m. depth of up to 80% and a modulating frequency in the range 300Hz to 3kHz.

3. A.M. MEASUREMENT

Modulation depth ranges	5, 10, 15, 30, 50 and 100% f.s.d. modulation depth. Measurements of either peak or trough relative to mean carrier can be made.
Modulation frequency range	50 Hz to 10kHz.
Accuracy	Better than ± 3% of f.s.d. and ± 2% of reading up to 95% modulation over the modulating frequency range 300 Hz to 3 kHz; ± 0.5dB with respect to the above over the modulating frequency range 50 Hz to 10kHz.
Residual a.m.	Less than 1% modulation.
F. M. Rejection	Additional a.m. error is less than 1.5% with peak deviation of up to 100kHz.

4. I.F. OUTPUT

Frequency	500kHz, nominal.
Level	100m V r.m.s. e.m.f., nominal.
Output impedance	600Ω nominal.

5. A.F. OUTPUT

Bandwidth	Normal: 50 Hz to 10kHz ± 0.5dB. With filter: 300 Hz - 3kHz at 2dB points.
Level	1V r.m.s., e.m.f., nominal, when meter is at f.s.d.
Output impedance	600Ω nominal.
Distortion	Less than 0.5% for f.m. deviations up to 100kHz. Less than 1% for a.m. depths up to 80% (typically 0.5%)

6. POWER REQUIREMENTS

Voltage	115V or 230V ± 10%
Frequency	45 to 440 Hz.
Power Consumption	Approximately 15VA.

7. ENVIRONMENTAL CONDITIONS

Operating temperature	0 to 55°C, 0 to 40°C with battery pack.
Storage temperature	-25 to + 70°C, -25 to +50°C with battery pack.

8. DIMENSIONS

Height 96.5 mm.
Width 240 mm.
Depth 268 mm.
Weight 2.5 kg approx.
(4 kg approx. with battery pack).

OPTIONS

Option 07 - Battery pack	10 rechargeable Nickel Cadmium cells give approximately 6 hours continuous operation. The charger in the 9009 enables cells to be trickle charged during normal mains operation. A discharged battery can be fully charged in approximately 14 hours by selecting CHARGE.

SECTION 2

DESCRIPTION & MAINTENANCE

CHAPTER 1

INTRODUCTION

INTRODUCTION

General

1.1 The Racal Modulation Meter 9009 provides a simple and unambiguous method of measuring the modulation depth of a.m. signals and the peak deviation of f.m. signals. A feature of the instrument is the entirely automatic tuning and level setting, with manual tuning also being available.

Operating Ranges

1.2 The automatic tuning is operative within the bands 10 to 13.0MHz and 20.0 to 26.5MHz, and continuously from 30MHz to 1GHz. By using a suitable (13-28MHz) external oscillator a manual tuning range of 6MHz to 1GHz is obtainable.

Facilities and Display

1.3 Measurements of peak deviation in eight ranges and modulation depth in six ranges are clearly displayed on a meter. A divide-by-two Meter Range switch enables readings always to be taken in the upper half of the meter scale where measurement is more accurate. A switched A.F. Filter is provided for use in conditions of high signal noise.

Input and Outputs

1.4 On the front panel there are two sockets for signal input; one (commonly referred to as the Low Level input) accepts signal levels in the range 10mV to 100mV up to 500MHz and 20mV to 150mV above 500MHz. The other (High Level) input has an operating range of 100mV to 1V up to 500MHz and 150mV to 1V above 500MHz. The third front panel socket is for the external oscillator input used in manual operation. On the rear panel the 500kHz i.f., the demodulated a.f. and a d.c. (analogue) output equivalent to the meter reading, are available at BNC sockets.

Operating Manual

1.5 For operating instructions and a description of controls, reference should be made to the Operator's Manual supplied with each instrument.

Battery Operation

1.6 The instrument is designed for operation either from normal a.c. mains supplies, or from an optional battery pack containing re-chargeable nickel cadmium cells, which can be fitted internally. The batteries allow approximately 6 hours continuous operation from the full charged condition and come into operation automatically whenever the a.c. supply is disconnected (See Note below).

IMPORTANT NOTE:

When the instrument is out of use (a.c. supply disconnected) check that the POWER switch is set to CHARGE, otherwise battery power will automatically come into operation with consequent discharge of the batteries.

1.7 With the battery pack fitted and the instrument connected to the a.c. supply the internal power circuit will operate as a battery charger whenever the POWER switch is set to the CHARGE position. Complete charging requires 14 hours although inadvertent over-charging up to 48 hours maximum will not cause any damage to the batteries. Long-term battery life may, however, be adversely affected if the batteries are allowed to charge for periods longer than 48 hours. When the instrument is operating from the a.c. mains supply the batteries receive a trickle charge which can continue indefinitely without detriment to the batteries.

Power Supply

1.8 The instrument operates from a nominal 115V to 230V a.c. supply, 45 to 440Hz. Soldered links within the unit must be correctly set according to the supply voltage to be used. (Refer to Chapter 4).

CALIBRATION

1.9 Calibration of the measurement circuits requires test equipment of high quality to match the specification of 9009, particularly with respect to low noise and modulation accuracy. The customer is recommended to take advantage of the calibration service offered by Racal Instruments Ltd and authorized Racal agents.

OPERATING INSTRUCTIONS

NOTE Before using the instrument for the first time, or at a new location, the power supply should be checked as described on page 4-3.

AUTOMATIC OPERATION

1.11 (1) Set the controls as follows:-

(i) POWER switch to ON.

(ii) AUTO/OSC switch to AUTO.

(iii) FUNCTION switch to A.M. or F.M., according to the signal to be checked.

(iv) A.F. FILTER to OUT.

(v) PEAK/TROUGH switch as required.

(vi) The two-position METER SCALE switch to the 3/100 position.

(vii) The METER RANGE switch to the 100/50 position.

(2) Connect the signal to be checked to the appropriate INPUT socket. If the amplitude is not known use the 1V r.m.s. socket initially.

(3) The IN LOCK lamp should show a steady illumination, if it continues to flash the cause is likely to be one of the following:-

(a) Signal level too high.

(b) Signal level too low.

(c) Signal frequency outside the automatic operating range.

To deal with (a) or (b) check that the appropriate input socket is in use.

(4) A meter reading may be taken as soon as the IN LOCK lamp gives a steady illumination. Set the METER RANGE and/or METER SCALE switches to give the most convenient indication on the meter scale.. Under noisy signal conditions the A.F. FILTER may be switched in IN.

(5) Read off the measurement from the appropriate scale on the meter, according to the settings of the METER RANGE and SCALE switches.

MANUAL TUNING OPERATION

1.12 (1) Connect a tunable oscillator with a range of 13-28MHz to the EXT. OSC. socket. (The required input level is 200mV-1V r.m.s. into 50 ohm).

NOTE: It should be appreciated that the oscillator frequency is divided by two, therefore the external oscillator frequency must be not less than 13MHz. This will ensure coverage of input signals down to 6MHz.

(2) Set the AUTO switch to EXT. OSC.

(3) Switch POWER to ON.

(4) Set the FUNCTION switch to TUNE and the A.F. FILTER to OUT.

(5) Connect the signal source to the appropriate INPUT socket.

(6) The METER switches are not relevant at this point and may be in any position; the meter will be displaying a steady reading at about half-scale.

(7) Tuning

NOTE: To avoid 'image frequency' tuning the following procedure should be followed exactly. The correct i.f. can be obtained at various settings of the external oscillator tuning, thus several meter responses may be found which will be of equal suitability provided the tuning procedure is followed precisely.

(i) Set the external oscillator initially to the higher frequency end of its range.

(ii) Tune the oscillator slowly downwards in frequency until the meter reading goes hard over to f.s.d.

(iii) At this point reverse the tuning direction and increase the oscillator frequency until the meter reading falls to the 'tune' diamond on the meter scale. This is the required tuning point.

(8) Set the FUNCTION switch to A.M. or F.M., as required.

(9) Set the METER RANGE and METER SCALE switches, as required, to give a suitable deflection for accurate measurement.

(10) Read off from the appropriate scale of the meter, according to the settings of the METER RANGE and SCALE switches.

CHAPTER 2

PRINCIPLES OF OPERATION

NOTE: In reading this chapter reference should be made to the explanatory block diagram Fig. 2.1 located at the end of this chapter. The overall block diagram Fig. 8 (at the back of the book) gives grecter detail, relating circuit functions to the separate p.c.b. Assemblies as well as showing interconnections.

SUMMARY

2.1 The Modulation Meter 9009 dispenses with the tedious tuning and level setting procedures of conventional modulation meters by exploiting the principle of the Sampling Mixer combined with a frequency - locked loop controlling a local oscillator. If required an external manually tuned oscillator may be used, which extends the operating range of the instrument.

2.2 The input signal, and the signal derived from the local oscillator are applied to separate inputs of the Sampling Mixer. By tuning the oscillator a point will be found at which a 500kHz "difference frequency" is obtained at the output from the Sampling Mixer. This is the required tuning point, which is achieved automatically by the oscillator control loop when on AUTO operation or by manual tuning when using an external oscillator.

2.3 The output signal from the Sampling Mixer (referred to as the i.f.) is offered two distinct paths:-

(a) Via an automatic level control (a.l.c.) stage to the a.m. and f.m. detectors of the measurement circuit.

and (b) Via a low-pass filter to the oscillator control loop.

2.4 The a.l.c. stage in the measurement path ensures that a constant mean i.f. signal level is applied to the a.m. detector. By virtue of this constant input level a reading of percentage modulation depth can be obtained by measuring the absolute value of the detected audio signal and applying this measurement to the meter. A 'peak and trough' switch permits measurement of both positive and negative-peaks of the modulating waveform.

2.5 On F.M. measurements the signal (i.f.) is applied to a 'pulse' discriminator which has an output level proportional to frequency. The amplitude of this output waveform has a mean level which corresponds to the i.f. Variations from this level represent positive and negative peak deviations. These variations are 'peak and trough' detected and displayed as a meter reading.

FUNCTIONAL DETAILS

2.6 The principles of the instrument will be now discussed in slightly greater detail.

Signal Input

2.7 Alternative front panel input sockets are provided. The "high level" input feeds into a 20dB attenuator whereas the "low level" input signal is applied direct to the input of the Sampling Mixer. The Input Attenuator and the Sampling Mixer are mounted on separate p.c.b. Assemblies. The remainder of the signal processing and measurement circuitry is mounted on a large p.c.b. referred to as the Motherboard.

Sampling Mixer

2.8 Referring to Fig. 2.1, the divided output from the voltage controlled local oscillator drives a pulse generator, thus producing a train of narrow pulses (fs) which are applied to an input of the Sampling Mixer. The external signal (fi) which is applied to the other input of the mixer, is sampled by this pulse train. If a harmonic of the sampling frequency 'fs' is identical in frequency to the external signal, the output frequency from the sampling mixer (the i.f.) will be zero. When the two frequencies are not identical a "difference" frequency output will be obtained.

2.9 The frequency relationship can be expressed by the formula:-

$$i.f. = (N.fs - fi)$$

where N.fs is that harmonic of fs closest to the external signal fi.

2.10 In AUTO operation it is the function of the control loop to sweep the oscillator (and hence the sampling frequency) until a 500 kHz difference frequency (the i.f.) is obtained at the sampler output. The oscillator frequency is then held at this point.

'In Lock Indication'

2.11 The IN LOCK lamp is driven by a multivibrator which has three control lines. The multivibrator will run and cause the 'IN LOCK' lamp to flash until the required conditions on the three control lines are satisfied. These lines are identified as A, B and C on Fig. 2.1. Measurements are not valid until the flashing indication is replaced by a steady illumination.

2.12 The conditions which can cause the IN LOCK lamp to flash are:-

Condition 1 ..... I.F. level (i.e. input level) too high (Control 'A')
Condition 2 ..... I.F. level (i.e. input level) too low (Control 'B')
Condition 3 ..... Input frequency out of range. (Control 'C')

The Oscillator Control Loop (Auto Operation)

2.13 Let it be assumed that the local oscillator, an AUTO operation, is searching for the required tuning point. The output from the Sampling Mixer (which is not yet at the required 500kHz) is applied via a low-pass filter and limiter to the discriminator stage.

2.14 The output from the discriminator is a d.c. voltage which is proportional to the frequency of the i.f. This d.c. voltage is applied to one of the inputs of an integrator, the other input being a fixed d.c. reference voltage. This reference voltage has a value such that when the frequency of the i.f. reaches 500kHz, the discriminator output level will equal the reference voltage.

2.15 The reference and discriminator voltages are summed in the integrator, the resulting output being applied as a tuning voltage to the oscillator, as follows.

2.16 For example, if the i.f. exceeds 500kHz the discriminator output level will be greater than the reference voltage and the integrator output will act to reduce the oscillator frequency until the exact 500kHz i.f. is achieved. At this point discriminator and reference voltages will be equal. The necessary oscillator search is initiated by a Hunt Generator circuit.

2.17 The function of the Hunt Generator is to produce a sweep voltage which will bring the oscillator frequency into the capture range of the frequency-locked loop. The discriminator voltage and the reference voltage (see para. 2.14) are compared in a Voltage Comparator circuit, the output of which controls the Hunt Generator. If a 'difference' exists between the two comparison voltages the Hunt Generator will remain in action until the two voltages almost coincide (i.f. approximately 500kHz). At this point the Hunt Generator turns off.

2.18 The output of the Voltage Comparator, which drives the Hunt Generator, is also applied as an 'out of range' signal to the In-Lock multivibrator circuit. (Control 'C' in Fig. 2.1). Thus, if the frequency locked loop is unable to lock because the input frequency is out of range, the Hunt Generator will remain in action and the In Lock multivibrator will maintain a flashing signal on the indicator.

In-Lock Detection System

2.19 The principles of the system are summarized in paras. 2.10 and 2.11. The three indication signals are applied to a triple And gate which controls a multivibrator. The out of range signal has been discussed in the previous paragraph. If, the input signal is too low (Control 'B') this is detected by a low level on the i.f. line to the discriminator. Too high an input signal, on the other hand, is notified by a d.c. voltage developed in the a.l.c. stage in the measurement path (Control 'A'). Until all three control conditions are satisfied the multivibrator will continue to run, thus maintaining a flashing signal at the In Lock indicator. Note that the system is "fail safe" in that the lamp is never turned off except when the instrument is inoperative. A failed lamp cannot cause misreading.

The Oscillator Output

2.20 The oscillator output is fed to the Sampling Mixer Assembly, where, after binary division it drives a pulse generator which in turn drives the sampling mixer.

Measurement Circuits

2.21 The measurement signal path is shown in heavy line in Fig. 2.1. From the input to the main board the i.f. is fed via a low-pass filter to the Auto Level Control (A.L.C.) stage.

2.22 For accurate a.m. measurement the mean carrier level of the i.f. must be constant; this is ensured by feedback from the a.m. detector to the a.l.c. stage.

2.23 The level-controlled i.f. signal is supplied simultaneously to the a.m. detector and f.m. discriminator, the required facility being selected by the Function (AM/TUNE/FM) switch. The TUNE position has no significance at this point.

2.24 From the Function switch the audio signal is fed via an amplifier and filter to the PEAK/TROUGH switch S5. This switch selects the signal either direct or via an inverting amplifier.

2.25 From the Peak/Trough switch the audio signal is offered alternative paths, either direct or via the a.f. filter. Filter selection is made by the A.F. FILTER (IN/OUT) switch on the front panel.

2.26 The four-position METER RANGE switch together with its associated toggle switch (for convenience referred to as the Meter Scale switch) effectively provides eight attenuation settings to accommodate a wide range of modulation depths, thus enabling most readings to be taken in the upper half of the meter scale where measurement is more accurate.

2.27 From the 2nd A.F. Amplifier the audio signal is fed to a peak detector and also to an A.F. Output socket on the rear panel. The peak detector provides a positive d.c. output to the meter, this d.c. signal also being available at a socket on the rear panel. The Peak Detector operates on positive half-cycles of the audio waveform. The Peak/Trough switch referred to in para. 2.24 enables both positive and negative peaks of the demodulated waveform to be measured.

Manual Tuning

2.28 For manual operation an external tunable oscillator may be connected to the EXT OSC socket. The oscillator requirements are a frequency range of 13 to 28MHz and output level between 200mV and 1V r.m.s. into 50 ohms. With the AUTO switch set to EXT OSC the internal local oscillator is inhibited and the external oscillator signal is fed via a buffer on the main board to the divider and pulse generator on the Sampling Mixer Assembly. To avoid the possibility of 'image frequency' tuning, the manual tuning instructions in the Operator's Manual must be followed precisely.

2.29 Although the internal oscillator frequency-locked loop has no control function when on EXT. OSC., the integrator output voltage is fed to the TUNE position of the

Function switch to provide a meter reading for manual tuning; the integrator for this purpose being converted to a fixed gain amplifier.

Battery Check

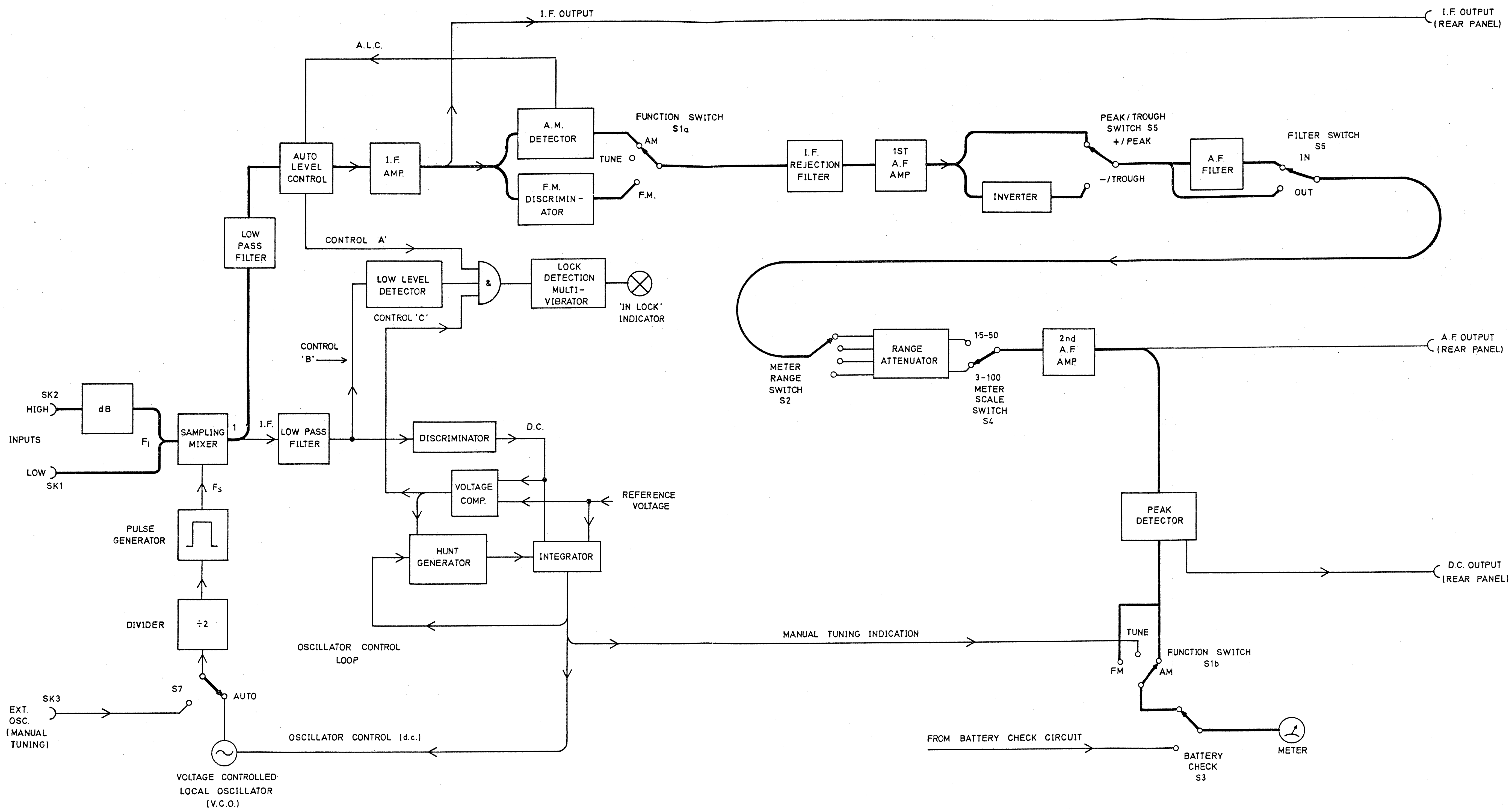
2.30 The state of charge of the battery pack (if fitted) can be checked by depressing switch S3 to BATTERY CHECK. This disconnects the meter from the modulation measurement circuits, and connects it to the battery check circuit. A reading within the green portion of the meter scale indicates a satisfactory state of charge. It should be noted that this check is valid only when the battery is on load. For this reason a reading can be obtained only when the a.c. supply is disconnected and the instrument is switched on.

Battery Charging

2.31 A mains-powered battery charging circuit is built into the instrument, although the battery pack is available only as an optional item. The batteries will receive a trickle-charge whenever the instrument is operating from an a.c. mains supply. The maximum charge rate is obtained by setting the POWER switch to CHARGE. The recommended charging time is 14 hours during which the instrument is inoperative. Advice on correct battery operation is given in Chapter. 1 and it is essential that this be noted.

A.C. Power Supply

2.32 The a.c. supply is connected via a 3-pin fixed plug on the rear panel feeding through a single line fuse and mains filter Assembly to the power transformer. Mains voltage selection is made by means of soldered links on a terminal panel inside the instrument. Instructions are given in Chapter 4. (Also in Chapter 2 of the Operator's Manual).



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Explanatory Block Diagram: Modulation Meter 9009

Fig.2.1

CHAPTER 3

TECHNICAL DESCRIPTION

INTRODUCTION

3.1 This chapter describes the significant features of the circuit design. The reader should have a clear understanding of the functional principles described in Chapter 2 and a basic knowledge of solid-state circuit theory and logic. The circuit descriptions will be dealt with under three main headings:-

(a) Input circuits, describing the input attenuator and Sampling Mixer Assembly.

(b) The main p.c.b.; in which the description will deal separately with

(i) The frequency-locked loop and oscillator.

and

(ii) The measurement circuits.

(c) The power supply and battery charging system.

INPUT ATTENUATOR 19-0761

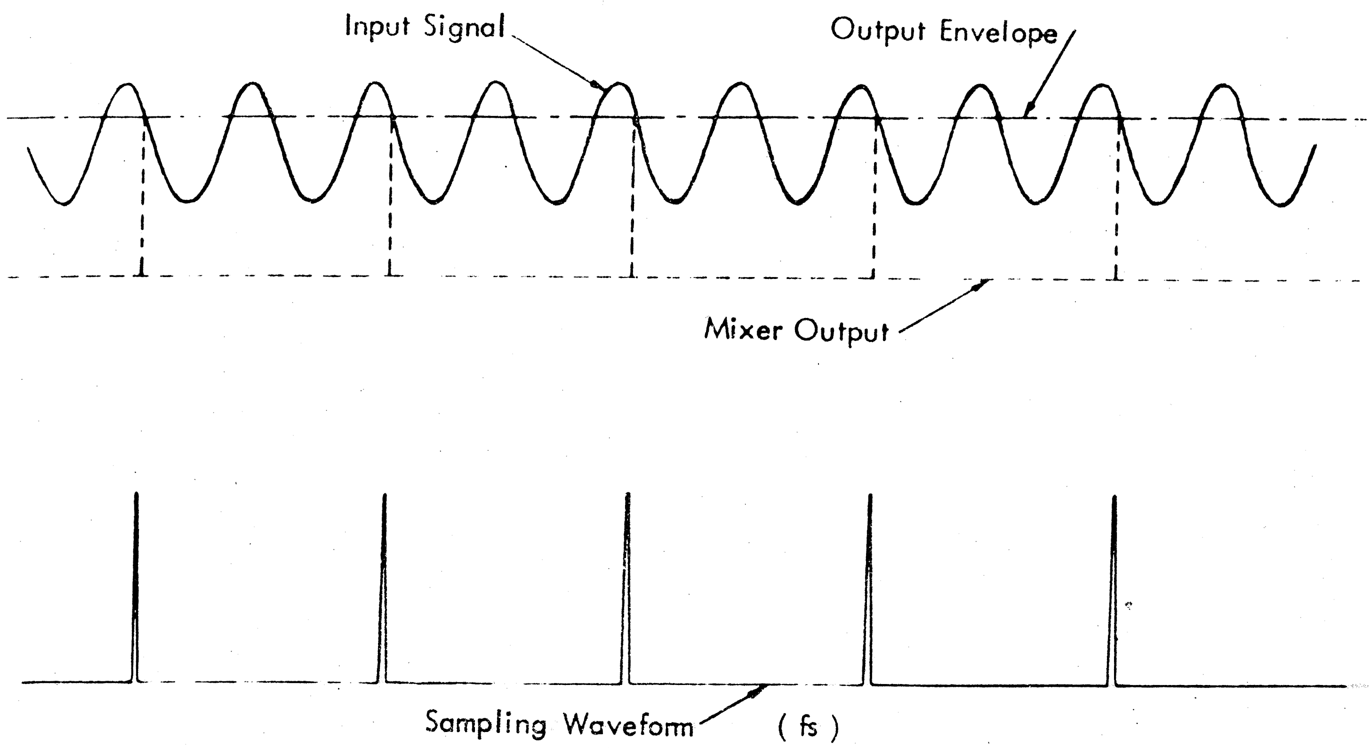
3.2 The input attenuator is mounted on a small board which is positioned close to front panel input sockets. Referring to the circuit diagram Fig. 1, signals at higher levels are fed in on input socket SK2 and conveyed via a length of 50 ohm transmission line to the 56 ohm terminating resistor R1. The attenuator is R2 which feeds into a 51 ohm terminating resistor on the Sampling Mixer Assembly (see Fig. 3). Capacitor C2 provides frequency compensation to equalise the response up to 1GHz. Low-level signals applied via SK1 are fed direct to the Sampling Mixer.

SAMPLING MIXER ASSEMBLY 19-0742

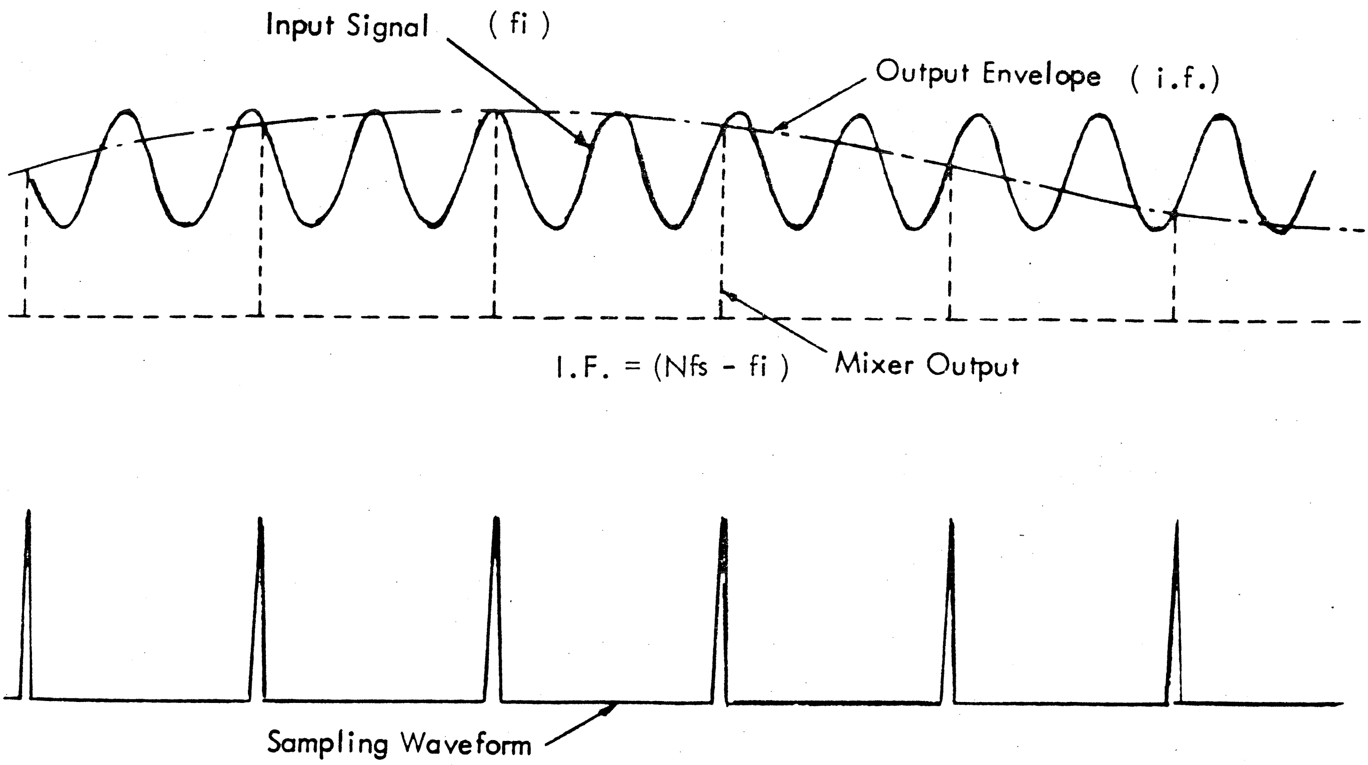
3.3 Referring to the circuit diagram Fig. 3, at the back of the book, this circuit may be considered, functionally, in two parts; the pulse generator section on the right of the diagram and a sampling mixer and i.f. output on the left.

Pulse Generator

3.4 The 20-28MHz signal from the local oscillator(either internal or external) is fed into IC1b which is one half of a high speed Dual-D package operating as a divide-by-two stage.



Sampling Waveforms in "Zero Beat" Condition Fig. 3.1



Sampling Waveforms in "Frequency Difference" Condition Fig. 3.2

3.5 From IC1b the divided oscillator signal is fed via shaper Q3 into a step-recovery diode pulse generator which produces a very fast pulse on the negative edge of Q3 collector output. The output from the pulse generator is fed in anti-phase via a transmission line transformer T1 to capacitors C2 and C3. The +5V supply to the divider and pulse generator section is stabilized by Q4 and D5.

The Sampling Mixer and I.F. Output

3.6 The external signal is fed via C1 to the junction of diodes D1 and D2 in the sampling bridge formed by D1, D2, R2 and R3. The positive and negative-going pulses from the pulse generator, which are fed via C2 and C3, briefly overcome the reverse bias of the sampling diodes, allowing a voltage related to the instantaneous value of the input signal voltage to appear on C2 and C3, this voltage being applied to the resistors R2 and R3 during the inter-pulse period.

3.7 If the sampling and signal frequencies are harmonically related the voltage applied to Q1 gate will be at zero frequency (d.c.), but if a frequency difference exists the output envelope will vary in amplitude at this difference frequency (the i.f.). The output envelopes for "zero beat" and "frequency difference" conditions are shown in Fig. 3.1 and 3.2. For a detailed discussion of sampling mixer principles reference should be made to a standard text book on the subject.

3.8 The output stage Q1/Q2 operates in a boot-strapped source-follower configuration with an overall gain of two. The i.f. output from Q2 collector is fed via pin 3 to the main p.c.b.

FREQUENCY-LOCKED LOOP AND OSCILLATOR CONTROL

Introduction

3.9 The circuitry for the frequency-locked loop and local oscillator is mounted on the main p.c.b. Essential diagrams for reference are the block diagram in Chapter 2 (Fig. 2.1) and the circuit diagram at the back of the book (Fig. 6).

I.F. Input Amplifiers

3.10 The i.f. signal from the Sampling Mixer enters the main p.c.b. at pin 1 and diverges into two paths. The description of the Measurement path commences at para. 3.44. Referring to the circuit, Fig. 6, the i.f. signal to the frequency-locked loop is fed via R201 into a low-pass filter which removes unwanted sampling mixer frequencies before offering the signal to the amplifiers Q204 and Q207.

3.11 Transistors Q204 and Q207 are high-gain shunt feedback amplifiers with constant current supplies via Q203 and Q206 respectively. The diodes D203 and D207 are limiters which prevent saturation of Q204 in the presence of high level input signals.

3.12 The output from Q207 (at test point TP15) diverges into two paths:-

(a) Via C211 into the discriminator circuit for oscillator control purposes.

(b) Via C207 to the Level Detector for "signal level too low" detection.

The low-level detector will be discussed in a later paragraph (para. 3.42).

Discriminator

3.13 From Q207 the i.f. signal is fed via C211 and R219 to the base of the switching amplifier Q209 which gives a square wave output. The collector of Q209 is fed from a stabilized +7V supply to ensure constant output amplitude. The catching diode D209 ensures correct biasing of Q209 in the event of excessive signal amplitude or overmodulation.

3.14 Q209 switches alternately hard on and off in response even to small i.f. inputs. During the conducting period the capacitor C213 charges from the +10V supply via D202. When Q209 switches off, however, its collector voltage rises towards +7V and Q210 becomes forward biased by the voltage stored on C213. This allows the stored charge in C213 to flow into C214 and R223. The current pulses flowing from Q210 are smoothed by C214 and the average current flows through R223, producing a mean d.c. voltage which is proportional to the frequency of the i.f. signal. This mean voltage is applied to the base of Q211.

Integrator

3.15 The d.c. output from the discriminator at Q211 emitter (Test Point TP16) is fed via a potential divider network R229, R232 to the integrator-operational amplifier IC202 via the input resistor R233. The output at IC202/6 is applied via link LK1 to the varactor control of the local oscillator Q230. Link LK1 is provided to permit the frequency control loop to be broken for test purposes.

3.16 A reference voltage supplied via Q226 and preset by R295 is applied via R234 to IC202/3. The control voltage developed at IC202/6 will adjust the local oscillator frequency (and hence the i.f. via the sampling mixer) until the discriminator output (at TP16) equals the reference voltage at TP18. When this occurs the control loop has reached the locked condition.

3.17 Capture Range. The ability of the integrator to tune the oscillator over a certain frequency range and achieve this locked condition is referred to as the capture range of the loop. Outside this capture range a hunt generator comes into action and applies a sweep voltage to pin 2 of IC202 via Q213 or Q214. This is discussed in more detail commencing at paragraph 3.22.

3.18 The diodes D210 and D215 are reverse-biased on AUTO operation; their function is relevant only to manual tuning (see para. 3.43).

Local Oscillator

3.19 The oscillator is a field effect transistor (FET) Q230 with voltage variable capacitance (varactor) diodes D211 and D212 operating in a Colpitts type circuit. The oscillator output is taken via a tap on inductor L203 to the base of output amplifier Q229 which is over-driven by the oscillator signal, thus feeding a square wave output to the Sampling Mixer p.c.b.

3.20 To ensure minimum noise on the local oscillator signal it is important to remove any extraneous noise or hum voltages from the varactor control line. This is accomplished by the time constant R284/C234. However, to ensure rapid lock-up, R284 is by-passed by Q232 during the time that the hunt waveform is operative. The control signal for this is obtained from IC203 pin 11 via Q233.

3.21 For manual tuning operation the AUTO/EXT OSC. switch S7a is set to EXT OSC which disconnects the +10V from R277/C228, thus inhibiting the local oscillator (and also the hunt generator). The output amplifier Q229, however, remains operative to accept the external oscillator signal from front panel socket SK3 via switch contact S7b and C221.

Hunt Generator

3.22 The Hunt Generator comes into operation (in AUTO mode) when the i.f. lies outside the capture range of the control loop as described in para. 3.16. A quite complex circuit is provided to sense the requirement for hunt generator action and to switch it on and off at the appropriate points. The items particular to the hunt generator system are IC201, IC203, Q213, Q214, Q216, Q217, Q219 and Q221 to Q227. A general description of the hunt control process will be given first, with additional circuit description following at para. 3.35.

3.23 The hunt process operates by turning on either Q214 or Q213, which feeds current into or out of pin 2 of the Integrator IC202. When Q214 is conducting the oscillator is made to hunt downwards in frequency, but when Q214 turns off and Q213 turns on, the loop hunts upward. When the loop is locked, however, both transistors are turned off.

3.24 If the frequency of the i.f. is low (below 500kHz) hunt generator action is not required because the frequency will be within the capture range of the loop. If, on the other hand, the i.f. is high, the hunt generator will be triggered into action when the frequency reaches about 700kHz.

3.25 The need for hunt generator action is determined by the d.c. level at the emitter of Q211 (discriminator output). This voltage is applied via R230/R224 to IC201/3. IC201/2 is supplied with a reference voltage from the same source which supplies the integrator IC202.

3.26 IC201 behaves as a Schmitt Trigger, the output voltage at pin 6 switching between high and low according to the voltage at pin 3 relative to the reference on pin 2.

3.27 For example, if the voltage at Q211 emitter goes high (indicating a high i.f.) it will cause IC201/6 to go high, which via Q212 will apply a '1' to IC203/1. If, at the same time, the latch gate IC203b/IC203c signals a '1' to IC203/2, then a '1' will appear at IC203/11 thus turning on Q213 and initiating an upward hunt at the oscillator.

3.28 The oscillator will hunt up towards the next 'lock' frequency. As it approaches this frequency the voltage at Q211 emitter falls and when it reaches about 2V (i.f. approximately 200kHz) the Schmitt circuit IC201 will switch back again, causing IC201/6 to go low and thus applying a '0' to IC203/1 via Q212.

3.29 This causes IC203/3 to be a '1' and leaves control of the gate IC203d to the signal on IC203/13. In normal operation IC203/13 will be a '1' and therefore the 'hunt up' transistor Q213 will be turned off by IC203/11 going to '0'. The i.f. having been brought within the capture range, the loop will now self-lock, the final tuning being carried out as described in para. 3.16.

3.30 The Schmitt Trigger IC201 will not change state again unless the discriminator output once again rises to about 7V (i.f. 700kHz) at which point IC201 will switch over, thereby carrying on the hunt until the loop tuning is once more within the capture range of the next higher lock frequency.

3.31 Precautions are taken to prevent the oscillator operating at the extreme ends of the tuning range. It has been explained that the oscillator search is always upwards towards the next locking frequency and this is true unless the top end of the oscillator tuning range is reached.

3.32 If this occurs the latch gate IC203b/IC203c will trip, giving a '0' on IC203/8 (which via IC203a and IC203d will switch off Q213). At the same time the '1' which is produced on IC203/6 will turn on Q214 via Q216, thereby applying a 'hunt down' signal to pin 2 of Integrator IC202. This hunt down will continue until the latch gate IC203b/IC203c is tripped to the opposite state.

3.33 The precautionary control described in the previous paragraph is carried out by a circuit involving transistors Q216, Q219 and Q221 to Q228. Of these, Q225, Q227 and Q228 are concerned with the provision of a fixed reference voltage; Q216, Q221 and Q222 are concerned with the 'hunt down' command whilst Q219, Q223 and Q224 are concerned with the 'hunt upwards' command.

3.34 These operations are controlled by referring to the level of the oscillator tuning voltage, a reduced version of which is taken from the junction of R255/R256/287 to the emitters of Q224 and Q222. Fixed reference voltages derived from Q228 via Q225/Q227, are applied to the bases of Q224 and Q222. Thus the oscillator tuning voltage is compared with a reference voltage to determine whether hunt action is required. The action is as follows:

3.35 If the voltage on the oscillator tuning line rises above approximately +7V it will cause Q222 emitter to rise above the reference level (approx. 6.3V) at its base and Q222 will conduct. The collector current of Q222 will turn on Q221, which pulls IC203/5 down to '0' level. This forces IC203/6 to a '1' condition thus turning on Q216 and also Q214. The latch gate IC203b/IC203c is held in this condition by the feedback to IC203/4.

3.36 The turning on of Q214 applies a hunt down signal at IC202/2. At the same time the '0' on IC203/8, applied via IC203a and IC203d, holds off Q213.

3.37 Once IC203b/IC203c has changed state it will remain latched to the 'hunt down' condition until switched back by a command derived from the 'low' threshold of the oscillator tuning voltage. This command is routed via Q224, Q223 and Q219 in response to the voltage at the junction R255/R256/R287 falling below the reference level of Q224 base.

3.38 The base of Q224 is supplied with a positive reference voltage (approx. 3V) derived from the level at Q227 emitter. When Q224 emitter falls to about 2.3V, Q224 will turn on, causing Q223 and hence Q219 to turn on. This applies a '0' to IC203/10, thereby tripping the latch bistable IC203b/IC203c, causing Q216 and Q214 to turn off thus stopping the 'hunt down' action.

3.39 The '0' at Q219 collector is applied to IC203/13, and immediately sends a '1' to turn on Q213, thus restoring the 'hunt upwards' command. This command will continue until Q219 is once more brought out of saturation by Q224 being turned off by a rising voltage on the oscillator tuning line; the control of Q213 will then revert to the Schmitt Trigger IC201 as described in para. 3.25. The feedback via D205/R260 delays the turning off of Q224 to avoid 'chattering'.

"In-Lock" Indication

3.40 The front panel lamp flashes in the 'out of lock' condition due to the output of IC204, which acts as a multivibrator as a result of the feedback into pins 2 and 3 of the IC, the switching time constant being determined by the values of R257 and C220. Switching will be continuous until pin 3 of IC204 is grounded by the turning on the AND gate transistor Q220, which can occur only when all functional conditions are satisfied (see Chapter 2 para. 2.11).

3.41 The control of Q220 is effected by a direct line to Q220 base from the a.l.c. circuit ("signal level too high") (refer to para. 3.55) and by Q218 which has three control lines to its base. The three control lines to Q218 base are:-

(a) Two lines indicating the 'hunt generator' command state (from IC203/6 and IC203/11 respectively).

(b) One line from the "Low Signal Level" detector via D201.

All these lines must be at '0' for the In Lock condition. The low signal level detector is described in the next paragraph.

Low Signal Level Detector

3.42 The amplified i.f. at Q207 collector is applied via C207 to the base of amplifier Q202, which is biased via Q201 so that it is conducting only on positive half cycles. The output, which is smoothed by C209, biases Q205 into the conducting state provided the signal level is adequate. This turns on Q208 and turns off diode D201, leaving the control of Q218 to the other two lines. If the signal is too low, the signal at Q208 collector will be a '1', thus turning on Q218 which holds Q220 in the non-conducting state and ensures that IC204 causes the IN LOCK indicator to flash.

External (Manual) Operation

3.43 Referring to the circuit diagram, Fig. 6, when the AUTO/EXT OSC switch S7 is set to EXT OSC the frequency control loop is affected as follows:-

(a) The local oscillator is rendered inoperative by disconnection of the +10V supply via S7/A from pin 62.

(b) Switch S7A also disconnects the +10V supply from part of the hunt generator (Q217, Q223, Q224), thus inhibiting the hunt generator transistors Q213 and Q214.

(c) Switch S7C in the EXT OSC position connects the output of IC202 via R291 and pin 53 to the summing input at IC202/2, thus converting IC202 from an integrator to a conventional amplifier. Manual tuning calibration is provided by potentiometer R235, through which a predetermined current is fed via R285 and switch S7C into the summing junction IC202/2. For external operation R235 is preset so that when a 500kHz i.f. is tuned in, the meter needle lies on the correct tuning point (the tune 'diamond' on the scale).

(d) Switch S7A in the EXT OSC position connects +10V to the junction of R292/R235. This applies a forward bias to D210/D215 which allows the discriminator output via IC202 to pass to the Function switch for meter indication of the manual tuning (TUNE mode).

(e) Switch S7b connects the external oscillator to the oscillator output amplifier Q229.

THE MEASUREMENT CIRCUITS

Introduction

3.44 Referring to the Theoretical Block Diagram, Fig. 2.1, in Chapter 2, it can be seen that the Measurement path includes the following principal stages, all of which are mounted on the main p.c.b. Circuit details are in Fig. 7 at the back of the book:-

Automatic Level Control (a.l.c.)

A.M. Detector and F.M. Discriminator

A.F. Amplifiers

Range Attenuator

Peak Detector.

I.F. Input

3.45 On AUTO operation, when the oscillator loop is locked, the 500kHz i.f. enters the main p.c.b. on pin 1 and is fed to the a.l.c. stage via a low-pass filter (formed by R1, C1, L1, C2, C56 and R6) which eliminates unwanted frequencies coming from the sampling mixer.

A.L.C. Stage

3.46 Summary. The voltage gain between the input (R6) of the amplifier and the output (Q5 collector) is determined by the current flowing through Q1. This in turn is controlled by the voltage applied to the base of Q1 by the integrated circuit amplifier IC1.

3.47 The amplifier IC1 compares an a.l.c. signal fed back from the a.m. detector Q22 with a d.c. reference voltage determined by zener diode D1. Any error signal so produced is applied by IC1 to the base of transistor Q1, which varies the gain of the Q1/Q4/Q5 configuration such as to maintain a constant i.f. level (at TP4) into the i.f. amplifier Q6/Q7/Q8 and thence to the a.m. detector Q20/Q21/Q22.

3.48 The correct condition is obtained when the half-wave rectified output from the a.m. detector Q22 has a mean level of approximately 0.5V. In this stable operating condition the feedback from the a.m. detector will produce a mean level of 3.9V on IC1 pin 2 (see also para. 3.55). The a.m. component in this feedback is actively filtered by C4 with R54 and R2/R3 to provide a d.c. control voltage on IC1 pin 6.

3.49 To avoid undue lag in the a.l.c. system the diodes D3 and D4 limit the change of voltage on C4 (between the "signal" and "no signal" conditions) to approximately 0.5V.

3.50 The a.l.c. stage provides a convenient source for the "signal level too high" control of the In Lock indicator system, using the current in Q1 as an information reference, as follows.

3.51 The d.c. current in Q1 flows through Q2. This current, and hence the voltage across R8/R9, is proportional to mean signal level. By adjustment of potentiometer R9 it can be arranged that Q3 will conduct when the input signal reaches the prescribed maximum level, thereby applying a signal to the triple AND gate (Q220) of the In Lock circuit (see para. 3.41).

I.F. Amplifier and A.M. Detector

3.52 From Q5 the i.f. signal at constant mean level is fed to the i.f. amplifier Q6/Q7 and Q8, operating in a "virtual earth" configuration. R14 and R16 with C10 and C11 form a band-pass filter centred on 500kHz. A high-pass filter in the feedback network from Q8 is provided by R18, R19 and C14. From Q8 collector the i.f. signal is fed to the a.m. detector via C29 and to the f.m. discriminator via C17. An i.f. output is also provided on the rear panel (SK4).

3.53 A.M. Detector. The a.m. detector is the virtual earth amplifier Q20/Q21/Q22, together with diodes D15 and D17 and resistor R52. The 3.9V reference from the a.l.c. stage is applied to the base of Q21, thus the detected a.m. component will be added to this 3.9V reference.

3.54 The output at the collector of Q22 is fed to diodes D15 and D17. On negative half cycles D17 is reverse biased whereas D15 conducts to the virtual earth line, thus no signal voltage is developed across R52.

3.55 On positive half cycles, however, the situation is reversed and the detected voltage appears at the junction D17/R52 to drive the output emitter follower Q23. Under stable operating conditions this detected voltage has a level of 3.9V (reference) plus a mean level of approximately 0.5V for the superimposed positive half cycles. This 4.4V signal is supplied to the a.l.c. feedback path where R54 (with R2/R3) attenuates it to a mean 3.9V level.

3.56 The detected signal, described in the previous paragraph, is also fed from the emitter of Q23 to the A.M. Calibration potentiometer R53 and to the Function switch (on A.M. mode) thence to the first a.f. amplifier.

3.57 F.M. Discriminator. Transistors Q9/Q10 with Q12 are arranged as a limiting amplifier which saturates when driven by the constant i.f. signal, thus providing a square wave output at Q12 collector.

3.58 The d.c. supply is 10V and potential divider R25/R26 ensures that the base of Q9 is biased to +5V, therefore with no external signal applied the base of Q10 will acquire a mean level of +5V. When a signal is applied the output at Q12 collector (TP6) will be a square wave with 1:1 mark/space ratio, a mean level of +5V and peak to peak amplitude of approximately 9V.

3.59 The significant components of the F.M. Discriminator are Q14, R34, C24, D7 and Q15. Transistor Q14 is a saturating amplifier driven by the square wave output from Q12 and thus switches on and off at the frequency of the i.f. signal. When Q14 is conducting it draws a charging current through D7 into C24.

3.60 When Q14 turns off the junction R34/C24 attempts to rise to +7V. This voltage is effectively added to the stored voltage in C24 and thus forward biases the base-emitter junction of Q15, which allows the stored charge in C24 to be transferred to the collector circuit of Q15. The output from Q15 therefore consists of a succession of current pulses at the switching frequency of Q14. This pulse type output is filtered by C26 in the amplifier Q16/Q17, the mean output voltage being determined by R38.

3.61 Since the quantity of energy stored in C24 in a given time period is proportional to the switching frequency of Q14, it follows that the mean voltage at the output of the amplifier Q16/Q17 will be proportional to the frequency of the i.f. and hence will vary according to the frequency deviation. From Q17 the output is fed via a calibrating potentiometer R42 to the F.M. position of the Function switch.

+7V Rail Stabilization

3.62 A stable +7V supply is essential to ensure a constant rate of charge in C24 for F.M. detection. Transistors Q18 and Q19 form the stabilizer circuit which functions on conventional lines; the diodes D8 to D11 provide temperature compensation which ensures stable performance in the f.m. discriminator.

A.F. Circuits

3.63 From the Function switch the detected signal, either a.m. or f.m., is fed through the amplifying and filtering stages associated with Q24/Q25, Q26 and Q27. From Q27 the audio signal is fed either through the unity-gain inverting amplifier Q28/Q29 (TROUGH selected) or direct via the PEAK position of switch S5 to the A.F. Filter and Range attenuation network.

3.64 A.F. Filter Switching. In the OUT position of the A.F. Filter switch S6, the signal path is via R76, R78 and switch contact S6b to the Meter Range switch S2. High frequency lift (to compensate for "droop" in preceding i.f. filters) is provided by C41 and further i.f. filtering by C44 and C47 in series.

3.65 With the A.F. Filter switch at IN both R78 and C44 are by-passed by the switch. This gives a filter which peaks at 1kHz and is 3dB down at 300Hz and 3kHz. Beyond these points the signal attenuation becomes 6dB per octave.

3.66 A useful feature of the a.f. filter is that at 1kHz there should be no significant change in output level between the IN and OUT positions of the A.F. Filter switch.

Meter Range Attenuator

3.67 The adjacent settings of the Meter Range switch (3, 10, 30, 100) have a 10dB relationship, these 10dB attenuation steps being provided by the network R77 and R79-R85. The front panel toggle switch S4 (referred to as the Meter Scale switch) follows the Meter Range selection and can add either 0dB (1.5-50 position) or a further 6dB of attenuation (3-100 position) thus effectively giving eight ranges to the Meter Range switch.

2nd A.F. Amplifier

3.68 From the Range Attenuator the a.f. signal is fed via switch S4 to the amplifier Q30/Q31/Q32. This is a high gain virtual earth amplifier with d.c. coupling. From the junction of R95/R96 an audio output at 600 ohms impedance is supplied to the rear panel outlet (SK8).

3.69 The diode D18 is an interesting design feature. Its purpose is to ensure that the output meter gives a hard-over deflection if the instrument is overloaded by too high

Stabilizing Circuit

3.76 The rectifier and stabilizing circuits operate on conventional lines but with additional protection for the battery. The output of the bridge rectifier D151-D154 is smoothed by the reservoir C1 (which is mounted on the side member). The rectified output is regulated by the power transistor Q1 controlled by Q154 and the long-tailed pair Q152/Q153. One side of the pair is referenced to the zener diode D155 whilst the other side (Q153) senses the output voltage in the potential divider R161/R162/R163. The stabilized level is preset by R162.

3.77 An automatic power cut-off operates if supply voltages are too low. If a very low mains supply is connected, the regulating transistor Q1 may saturate, possibly causing false leadings. Alternatively, if the instrument is being operated from batteries it is desirable not to discharge the batteries completely, but to disconnect them if they are approaching the discharged condition. If either of these power conditions occurs the series regulator Q1 will automatically be turned off, thus cutting off the power to the remainder of the instrument. This protection is carried out by Q151 and D156.

3.78 Normally, Q151 will be held on by the voltage on zener diode D156, but if the voltage at the junction R152/R153 falls below the critical level D156 will switch off, thus turning off Q151 and the long-tailed pair. This will cause Q1 to be turned off, thereby cutting off the d.c. supply to the instrument.

Battery Charging System

3.79 Two battery charging modes have to be considered:-

(a) A trickle charge when the POWER switch is ON.

(b) A full rate of charge when the POWER switch is set to CHARGE.

3.80 Trickle Charge. Referring to the circuit Fig.4 , when the POWER switch S8 is at ON the negative supply rail is connected via current limiting resistor R167 to pin 36 of the p.c.b., thence via the ON contact of switch S8a to the negative terminal of the battery.

3.81 Full Charge Rate. The full rate charging path is via current sensing resistors R165/R166 in parallel, through diode D157 and the CHARGE contact of switch S8a to the negative terminal of the battery. The regulating system is switched to a higher output voltage by switching R168 in parallel with R161/R162 via the CHARGE contact of switch S8b, thus altering the value of the voltage sensing potentiometer. The charging current is controlled at approximately 0.4A by applying the voltage developed across R165/R166 to the base of Q156.

Power 'Off' on Battery Operation

3.82 When the a.c. supply is not connected to a battery-operated instrument the CHARGE position of the POWER switch S8 serves as the instrument 'off' switch. This is arranged by diode D157 which is reverse-biased when no negative voltage is present on the cathode side.

Battery Metering Control

3.83 It is arranged that a battery voltage reading can only be obtained when:-

(a) The a.c. supply is disconnected

and

(b) The POWER switch is set to ON.

These conditions are automatically enforced by transistor Q157 together with diodes D158 and D159, as follows.

3.84 Transistor Q157 is in shunt with the meter connections and will be held in a conducting state via R169 when battery metering is to be inhibited. When, however, the POWER switch is set to ON and the a.c. supply is disconnected, the negative battery voltage will be applied via switch contact S8a, pin 36 and D159 to the base of Q157, thus turning off Q157 and removing the shunt from the meter BATTERY CHECK connections.

3.85 When the a.c. supply is connected the trickle charge current through R167 will produce a volt drop which will make the cathode of diode D159 more positive than the emitter of Q157, thus allowing Q157 to conduct and maintain the inhibit on the BATTERY CHECK metering.