MEASUREMENT TECHNIQUES – PART 7

High-frequency measurements

by F.P. Zantis

THE test methods described so far in this series apply only to low-frequency (LF) equipment. In circuits carrying high-frequency (HF) signals the effects of the measuring equipment become an important factor. First of all, of course, the test instruments used must be designed for HF measurements. Also, unless suitable measures are taken, tests may result in reflections and radiation of HF energy, which will invalidate the test results.

Measuring HF voltages

The bandwidth of virtually all inexpensive voltmeters makes them unsuitable for measuring HF voltages. Moreover, the capacitance of the test leads and that of the input circuit of the instrument will adversely affect the measurement. Also, in case of instruments with a not very high input impedance, the circuit Q will be derated.

For accurate measurements of HF voltages special HF peak rectifiers are used. After rectification of the voltage, a standard DC instrument indicates the peak value of the measurand. It is then not possible to measure the r.m.s. value of non-sinusoidal voltages. The rectified voltage should be fed to the test point in a direct way to ensure that the leads from the test point to the display section have no detrimental effect on the measurement. In many cases, therefore, a probe as shown in Fig. 61 is used. The rectifier diode should have the smallest possible junction capacitance and this is met by germanium types. The wide-band properties of this diode determine the overall bandwidth in the first instance. The coupling between the tip of the probe and the diode is capacitive, so that any direct voltage at the tip is blocked. Errors in measurement are normally caused by incorrect earthing. The earth point of the probe should be as close as possible to the test point and be connected to the earth of the equipment on test. If the frequency is higher than about 1 GHz, even these measures are not sufficient, since part of the HF energy is then radiated by various components and the wiring, which, of course, makes the measurement invalid or even impossible.

For voltage measurements at frequencies up to about 2 GHz, coaxial insertion probes are used whose construction obviates the unwanted radiation.

Alignment of tuned circuits

Relative measurements suffice in the alignment of tuned circuits—see Fig. 62. Therefore, if a probe is not available, the measurement may be carried out by connecting a low-value capacitor, C, in series with the instrument. This reduces the effect of the input capacitance of the test instrument on the tuned circuit. The circuit is aligned by adjusting C_2 for maximum or minimum deflection of the voltmeter. In direct voltage measurements, the effect of the meter is reduced by connecting a high-value *carbon* resistor (which has a high parasitic inductance) in series with the meter. As in a probe it is advisable to connect the series capacitor or resistor close to the test point.

It will be realized that these simple methods can only be used for alignment and *not* for absolute measurements.

The effect of the instrument on the circuit on test can be reduced further by the absorption method, for which a circuit as shown in Fig. 63 is used.

Coil L_1 is brought close to the inductor of the circuit on test. Mutual inductance causes a potential across L_1 that may be fed to an oscilloscope or, after rectification, to a voltmeter. If, owing to screening of the inductor in the tuned circuit, inductive coupling is impossible, wiring that carries the HF voltage may be touched with the tip of the probe. Capacitor C_1 is adjusted for maximum voltage across the tuned circuit, after which the frequency can be read on the oscilloscope or, if this is provided, the scale of C_1.

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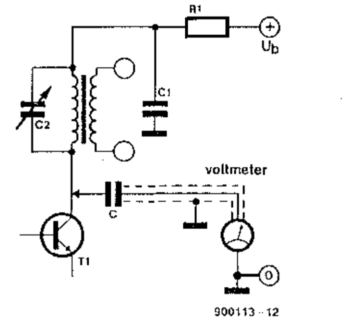

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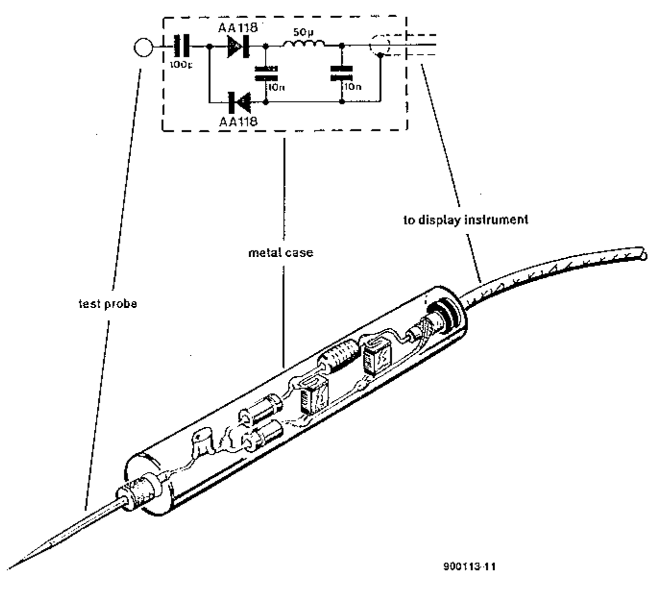

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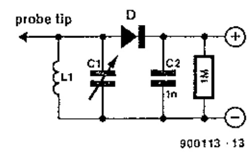

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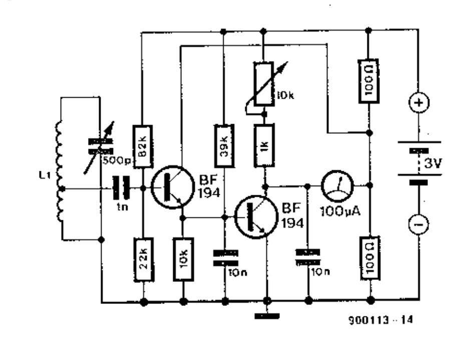
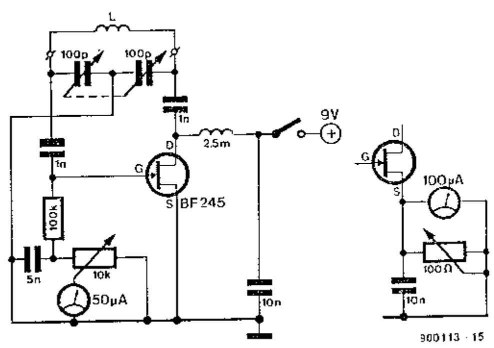


65 (A) (B)



To really minimize the effect on the tuned circuit, it is advisable to amplify the voltage obtained by inductive coupling. A suitable circuit is shown in Fig. 64. Coil L_1 may be a plug-in type to make alignment over a wide range of frequencies possible. The tap on the coil ensures matching to the low-impedance transistor input.

Dip meter

The dip meter is still the most popular instrument for the radio and television amateur. Although it is basically a small HF transmitter, the meter functions in a manner similar to the absorption method described earlier. This active instrument makes the effect on the circuit on test even smaller, and, of course, greater sensitivity is obtained.

As in the absorption meter, the frequency is read on the scale of the variable capacitor, while the meter serves merely as a maximum or minimum indicator.

Apart from its use as a resonant-frequency measuring instrument, the dip meter may also be used as a signal source in signal tracing in HF circuits.

The values of the coil and variable capacitor are readily calculated with the following formulas if the value of one and the frequency (in MHz) are known.

$$L = 25\,400/Cf^2 \quad [\mu H]$$

$$C = 25\,400/Ff^2 \quad [pF]$$

A suitable circuit based on a field-effect transistor—FET—is shown in Fig. 65. The HF signal is generated across the gain-drain junction. The display instrument is connected either in series with the gate bias resistor as in A or across the source as in B. The sensitivity of the circuit is set with the potentiometer.

When the circuit is used as an absorption meter and the display instrument is connected as in B, the 100 Ω potentiometer must be disconnected to ensure that the full sensitivity of the meter is available.

Winding data for coils are given in Table 1.

Measurements on transmission lines

The characteristic impedance of a transmission line is the value of load resistance that enables maximum power transfer from source to load. The characteristic impedance of a transmission line, Z_c, is given by

$$Z_c = \sqrt{(L_d/C_d)}$$

where L_d is the distributed inductance per unit length and C_d is the capacitance per unit length. Practical values of Z_c vary from 100 Ω to 1000 Ω for parallel wires and 10 Ω to 150 Ω for coaxial cable.

When a transmission line, such as that connecting a transmitter to its antenna, is terminated by an impedance different from its characteristic impedance, some of the forward signal wave is reflected back. The reflected wave mixes with the forward wave, and the resultant amplitude at any point of the transmission line is the algebraic sum of the amplitudes of the two waves.

The nodes and antinodes do not move relative to the transmission line, that is, they are stationary and the waves are called standing waves. An important consideration in transmission line and antenna design is the standing wave ratio—SWR.

The SWR may be ascertained with the aid of an SWR meter as shown in Fig. 66. The pick-up consists of three conductors of which the centre one is the core of the transmission line, while the outer two, called reflected pick-up wire (top) and forward pick-up wire (bottom), are spaced equally from this.

Usually the pick-up unit is made as a pattern on a printed-circuit board: a strip line. The 51 Ω resistors are, in this case, equal to the characteristic impedance of the transmission line (if this were 75 Ω, the resistors would also have to be 75 Ω). In operation, any RF signal on one of the pick-up wires will be rectified by the relevant diode and then applied as DC to the associated indicator.

To ensure that the indicators can be used independently of the actual power, their scales are calibrated in relative values. That in the forward pick-up circuit, F, shows the relative power as a percentage, whereas the other shows the SWR. The ratio is given by the formula

$$SWR = (1+U_r)/(1-U_r)$$

where U_r is the reflected voltage. It is assumed

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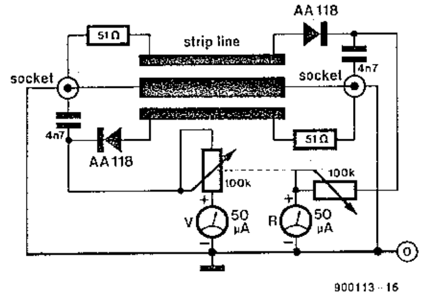

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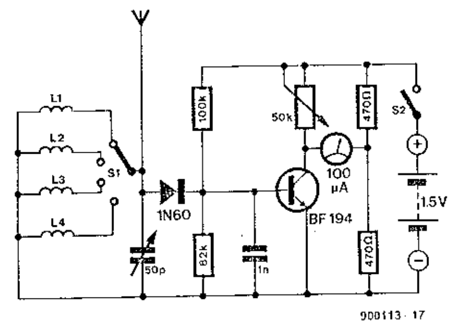

that the forward voltage has been set to 100% of the relative power. Optimum performance is of course established when $U_r = 0$. A good antenna system has an SWR that varies between 1:1 and 1:1.2. Poor systems have ratios greater than 1:1.5. Most SWR meters do not give a reading beyond 1:3.

Measurement of field strength

For tuning a transmitter or testing an antenna system, a field strength meter is almost essential. In its simplest form, such an instrument consists of a basic receiver in which the headphones have been replaced by a sensitive moving-coil meter. A possible circuit is shown in Fig. 67.

The meter is zeroed with the 50 kΩ potentiometer. For relative field strength measurements, the antenna circuit need not be tuned: setting the tuned circuit to the centre of its bandwidth is sufficient. Otherwise, a number of different inductors may be selected with the aid of switch S_1, which makes it possible to tune and test transmitters over a wide range of frequencies.

Table 1

Range	Frequency (MHz)	Inductance (μH)	No. of turns	Wire dia. (mm)
1	1 2–2 4	300	76	0.5
2	2 3–4 7	82	36	0.5
3	4 6–9 2	21	18	0.5
4	8 2–16 6	6 5	8	1.0
5	16 2–32 6	1 7	5	1.0
6	22 2–44 8	0.9	3	2.0
7	38 4–77 6	0.3	3	2 0
8	74.5–150 0	0 08	1	2 0

The coil diameter for ranges 1–6 must be about 38 mm (1.5 in.) and that for range 7, 25 mm (1 in.). The coil for range 8 is shaped like a hairpin, 50 mm (2 in.) long; wire separation is 10 mm (0.4 in.).

Finally

Instruments are usually multi-purpose: for instance, it is quite common for an SWR meter to be combined with a field strength meter and a power output meter.

Next month's instalment will deal with 'Measurements in digital circuits'.

ASYMMETRICAL-TO-SYMMETRICAL CONVERTER

by M. Eller

IT OFTEN happens in electrophonics (electronic music) that hum-and-noise loops occur when two or more different instruments are intercoupled as in Fig. 1a. Some musicians play with their lives by covering the earth pins with insulating tape to get rid of the hum. This is, of course, not only very stupid but also highly dangerous.

A safe and certain method of getting rid of these loops is offered by the converter whose circuit is shown in Fig. 2. The converter is connected between two instruments as shown in Fig. 1b to provide electrical separation of the instruments. Make sure that the 'isolated' instruments are not drawn into new hum-and-noise loops through a common enclosure: each and every instrument must be isolated from the enclosure.

The converter resolves another problem also. On cost grounds, many commercial instruments have only a relatively high impedance output. Even pick-ups often suffer from this. When long connecting leads are used, or the signal is divided, or a following instrument has a low impedance input, noise and hum are the result and the quality of the music suffers. The converter has a high impedance input and two low impedance outputs (one not isolated).

Circuit description

The input signal arrives at K_1 and from there it is applied via C_5 to IC_2, which is arranged

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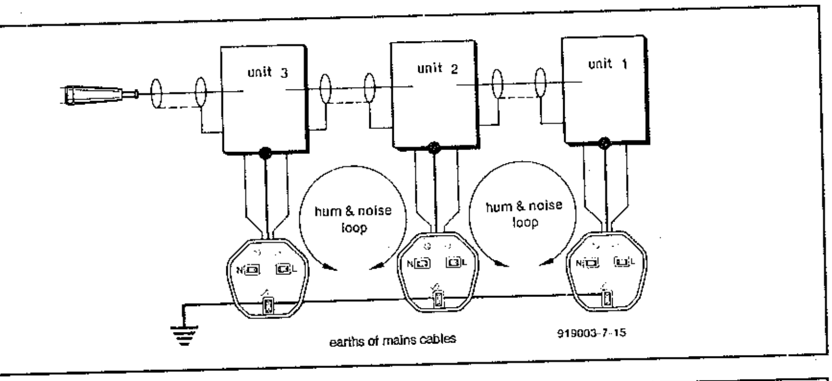

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