MEASUREMENT TECHNIQUES (5)

by F.P. Zantis

Audio-frequency technology is of particular interest to many electronics enthusiasts since it seems to surround us in our everyday life in the shape of television and broadcast receivers, audio amplifiers, equalizers, and so on. To keep such apparatus in tip-top condition, it is important to be able to test and check it with suitable equipment.

The first question that arises when audio-frequency (AF) equipment is to be checked or tested is what test gear is suitable. For example, a multimeter is only suitable if it is designed to work at frequencies between 30 Hz and 16,000 Hz. Such instruments are pretty expensive: a less expensive alternative is an audio-frequency millivoltmeter. Often, such an instrument is not readily available, but an oscilloscope is and this is perfectly suitable for audio-frequency measurements. Even the simplest oscilloscope has an operating range extending from DC to about 10 MHz. It should be noted, however, that an oscilloscope measures peak values while a multimeter or AF millivoltmeter measures root-mean-square (r.m.s.) values.

Apart from an oscilloscope or AF millivoltmeter, a function generator is required to provides sinusoidal and rectangular voltages in the audio frequency range.

The input resistance of most AF millivoltmeters and oscilloscopes is of the order of 1 MΩ. The resistors of the input voltage dividers in all test equipment intended for AF measurements are shunted by small capacitors of 1–500 pF. The reason for these becomes clear from Fig. 32. Here, the lower resistor of the 1:10 divider is shunted by the parasitic capacitance, estimated at 100 pF contained in the wiring and circuit. At a frequency of 16 kHz, this capacitance has a reactance of some 100 kΩ, which reduces the lower branch of the divider to 50 kΩ. Clearly this will cause a serious error in the measurement. To obviate this, a compensating capacitor is connected in parallel with the upper resistor of the divider. This solution has a disadvantage, however, in that the load presented by the measuring instrument to the measurand depends on the frequency, which is the reason for the limited frequency range of most instruments. The value of the input (i.e., compensating) capacitance is therefore always clearly stated on all instruments intended for operation at audio or high frequencies. The smaller it is, the better (and more expensive) is the instrument. But here again, when the cause of the error is known its effect can be estimated fairly accurately. Also, it should be remembered that

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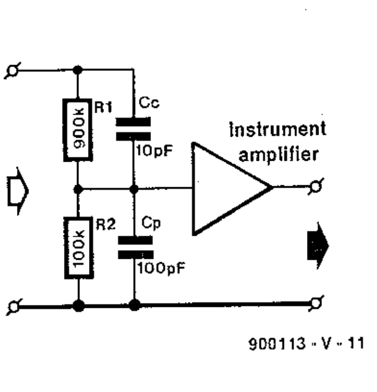

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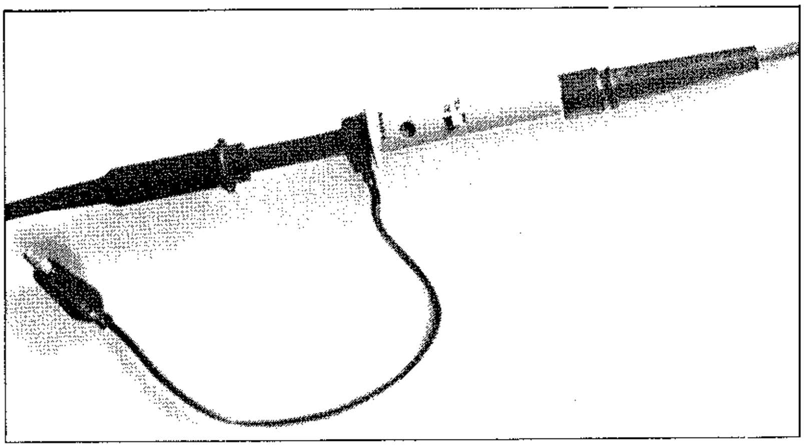

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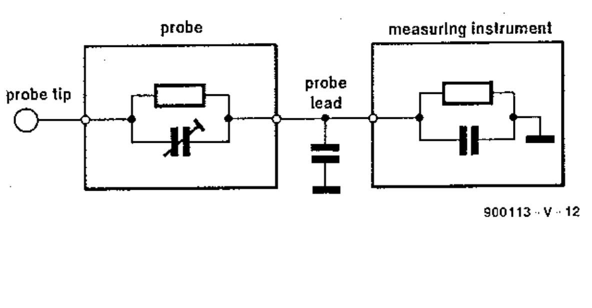

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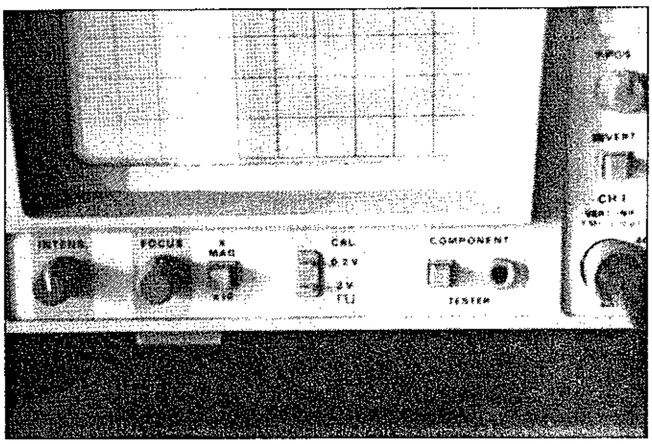

error-free measurements are not possible.

The capacitance of the screened cable of a probe as shown in Fig. 33 also affects the measurement and it has therefore to be compensated in a similar manner. For this, a variable trimmer as shown in Fig 34 is normally used The probe is calibrated with the aid of a rectangular voltage. Such a signal consists of a large number of sinusoidal voltages superimposed on each other If one or more of these sinusoidal voltages is attenuated, the rectangular signal becomes rounded Most oscilloscopes have an integral 1 kHz rectangular-signal generator for this purpose as shown in Fig. 35 (CAL) The frequency of this signal is often not very precise, although its level is stabilized and stated in the technical specification for instance, 0 2 V peak-to-peak ±1% The compensating capacitor is adjusted until the waveform on the screen of the oscilloscope is truly rectangular as shown at the centre of Fig 36

Measuring input and output resistance

The input resistance, R_i, of an audio circuit may be measured with a set-up as shown in Fig 37 if it is appreciably larger than the internal resistance, R_g, of the signal generator. The output frequency of the generator is 1 kHz A variable resistor, R_v, needs to be inserted between the generator and the amplifier input To keep the error introduced by the load presented by the measuring instrument small, the output voltage rather than the input voltage of the amplifier is measured. If $R_v = R_i$, the input voltage of the amplifier is halved, and so, of course, is its output signal. To be exact, R_g should be added to R_v If the input resistance of the amplifier is very low, the test set-up shown in Fig 38 should be used.

The output resistance of an amplifier may be ascertained with the set-up shown in Fig. 39. The unit under test, i.e., the amplifier, is driven, but not over-driven, by a tone generator First, the open-circuit output voltage, U_1, is measured and then the output voltage, U_2, across R_L. From the values of these voltages the output resistance, R_o, may be calculated as follows

$$R_o=R_L\{[U_1-U_2]/U_2\}$$

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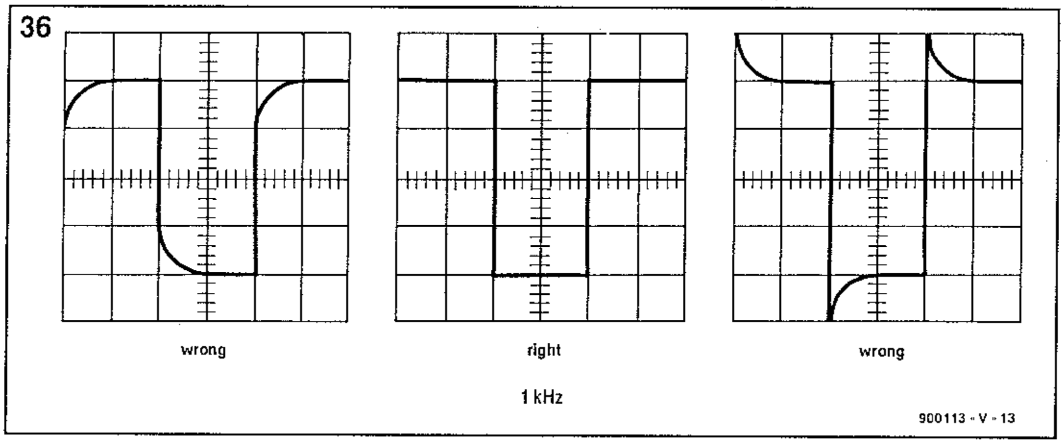

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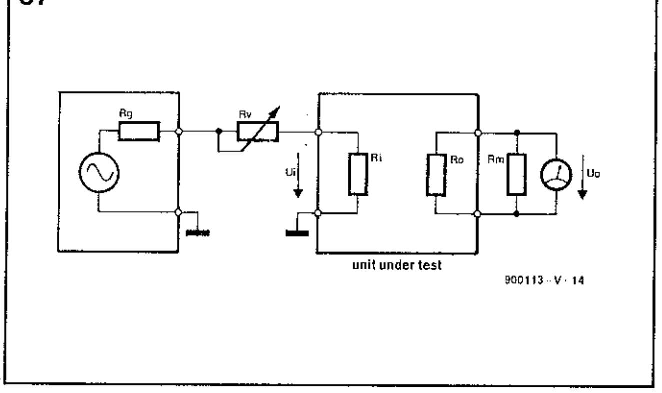

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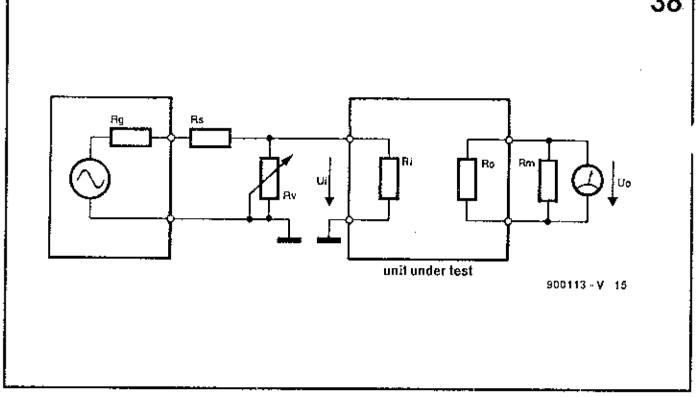

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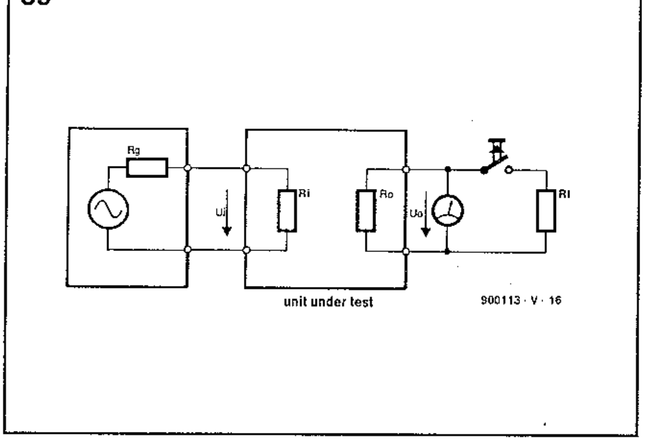

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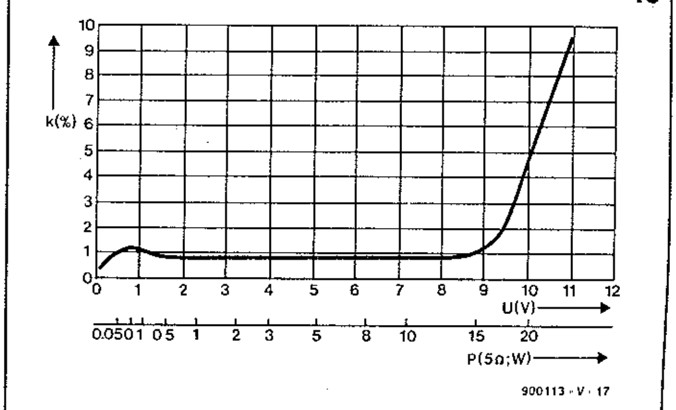

Some older amplifiers may have a tendency to become unstable under open-circuit conditions and then generate large spurious signals that not only invalidate the measurement, but may also damage the amplifier and the measuring instrument. It is therefore advisable to monitor the waveform at the output with an oscilloscope. This will also indicate if the amplifier is overdriven, which would also invalidate the test results.

Measuring output power

The specification of the output power of an amplifier is of practical use only if it includes the distortion, which is an indication of the non-linearity of the amplifier. The distortion increases rapidly when the amplifier is over-driven as shown in Fig 40. Normally, the output power is specified at a distortion of 1%. If therefore the output power needs to be measured exactly, a distortion meter must be used as shown in Fig 41. The amplifier, terminated into its nominal load R_L, is then driven till a distortion of 1% is indicated. The output power, P_o, is then

$$P_o = U_o / R_L$$

The decibel scale

The behaviour of audio components is often better observed on a logarithmic scale, which is calibrated in bel, B, or a tenth of this, the decibel, dB. These are dimensionless units expressing the ratio of two powers, currents, voltages, or sound intensities. The decibel is ten times the common logarithm of the power ratio or twenty times the common logarithm of the voltage or current ratio. Thus, if two powers P_1 and P_2 differ by n decibels,

$$n = 10\log_{10}[P_1/P_2]$$

and, if two voltages or currents differ by n decibels,

$$n = 20\log_{10}[U_1/U_2]$$

or

$$n = 20\log_{10}[I_1/I_2]$$

Low-frequency millivoltmeters and some good-quality multimeters have a decibel scale (see Fig 43 – lowest scale) that enables the ratio to be read directly. If, for instance, the gain of an amplifier is to be measured

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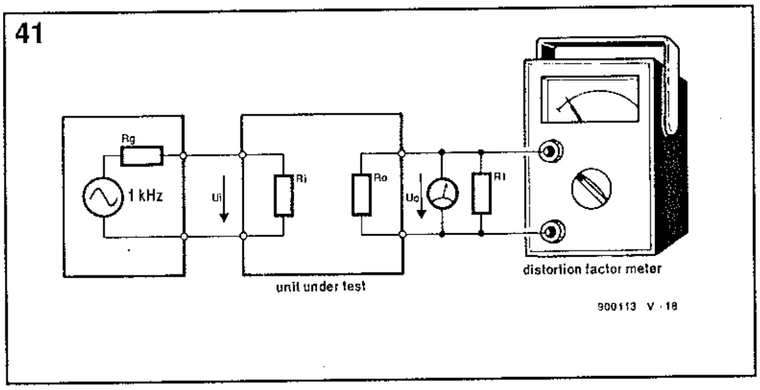

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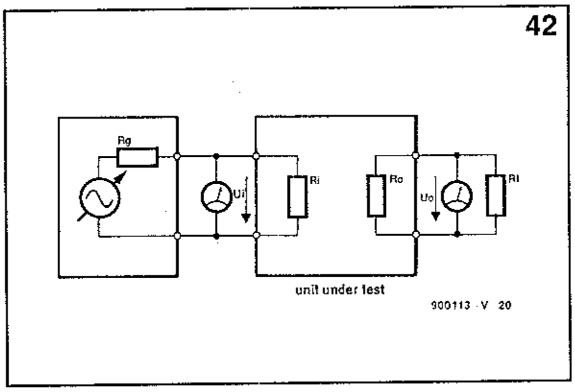

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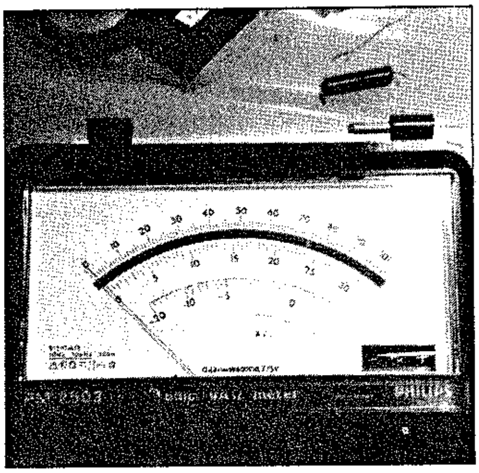

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f/Hz	A/dB
10	-8 67311
30	-5.29
100	-0.46962
300	0 0506
1000	0
3000	0.101
10000	0 200839
30000	0.2008
100000	-3 52182

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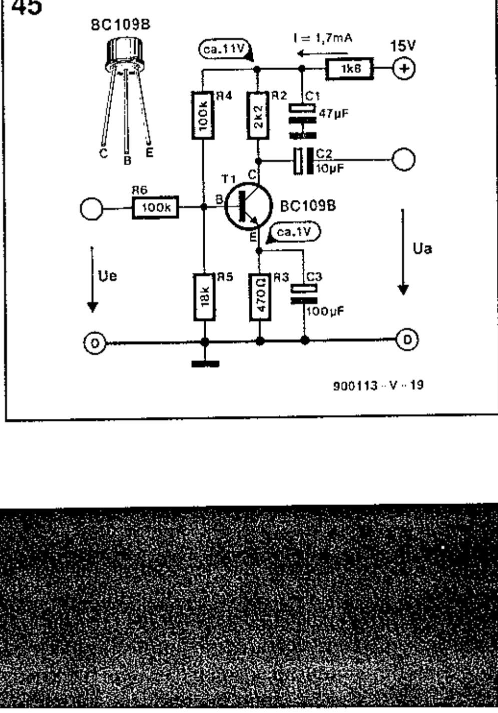

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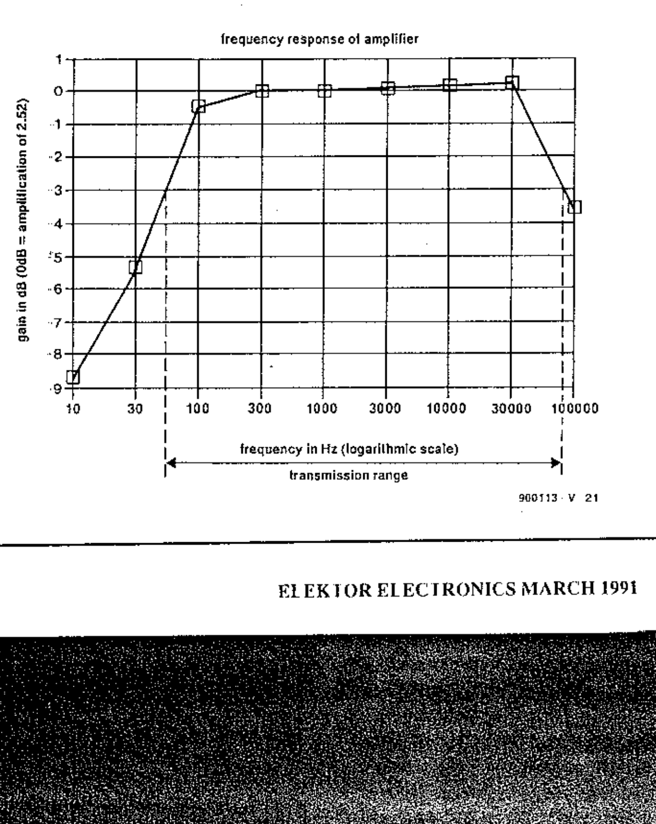


the amplifier is driven by a 1 kHz signal at a level at which it just is not over-driven. An AF millivoltmeter is connected across its input and the decibel scale read and noted. Then, the millivoltmeter is connected across its output and the decibel scale again read and noted. If the output is greater than the input, the difference between the two readings is the gain in dB; if the input is greater than the output the difference is the attenuation in dB.

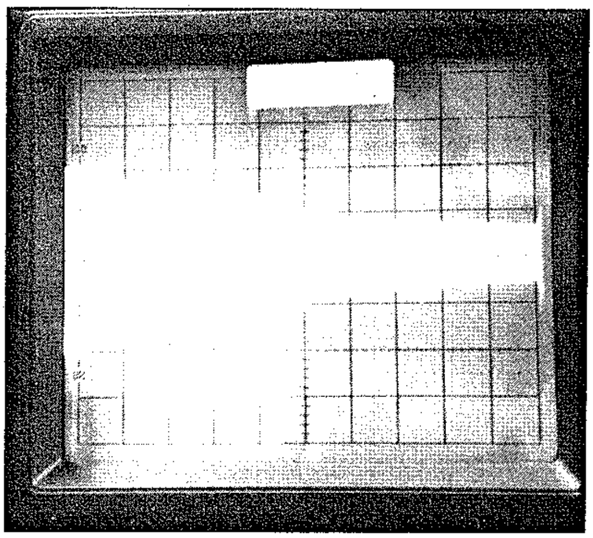
Measuring frequency response

The circuit diagram of a small audio amplifier is shown in Fig. 45. Its frequency response may be determined in a manner similar to that used for measuring its gain: the test set-up is shown in Fig. 42. With a 1 kHz signal input, the level is set to give an output of 0 dB. The decibel readings are noted when the frequency is changed to, say, 10 Hz, 30 Hz, 100 Hz, 300 Hz, 3000 Hz, 10 000 Hz, and 30,000 Hz. The more frequencies are used, the more exact the test result will be. A voltmeter is used in parallel with the signal generator to make sure that the input level to the amplifier remains the same. From the results, tabulated in Fig. 44, a frequency response curve as shown in Fig. 46 (relating to the amplifier in Fig. 45) may be drawn. The frequency range of the amplifier is that between the two −3 dB points.

This method of determining the frequency response requires no special or expensive instruments, but it is very time-consuming. Far more convenient is the use of a wobbulator, whose output is varied automatically over a predetermined range of frequencies. In the example discussed above, the frequencies would be varied between 10 Hz and 30,000 Hz. Moreover, its scanning rate may be synchronized with the horizontal deflection of the oscilloscope to give a stable trace on the screen. Some wobbulators give an additional sawtooth output to facilitate the synchronization with the oscilloscope's horizontal time base. This sawtooth may also be used in X-Y operation to deflect the horizontal trace. Figure 47 shows the screen image during measurements on a cable in this manner. The test set-up for this is shown in Fig 48: the frequency was varied from 10 Hz to 510 kHz; the horizontal scale was 50 kHz per division. The falling level of the signal at higher frequencies is quite evident.

The use of a wobbulator gives an appreciable saving in test time and the oscilloscope always shows a complete signal period, provided the wobbulator is adjusted properly. The peak-to-peak value of the signal is easily read from the screen.

The test becomes even more straightforward if the signal at the output of the unit under test is applied to the oscilloscope via a peak detector. The frequency response of the unit under test is then shown on the screen of thge oscilloscope as a curve. Again, the screen shows the peak values of the signal, but these may be converted to r.m.s. values with the aid of a voltage divider. The test set-up is shown in Fig. 49, while Fig. 50 shows the result when a band-pass filter is measured in this. ■



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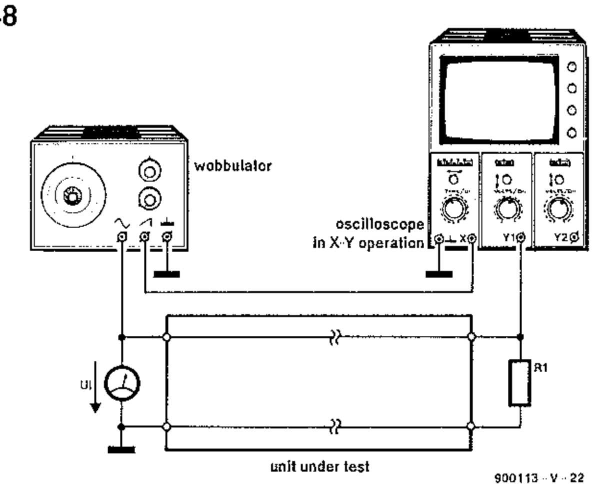

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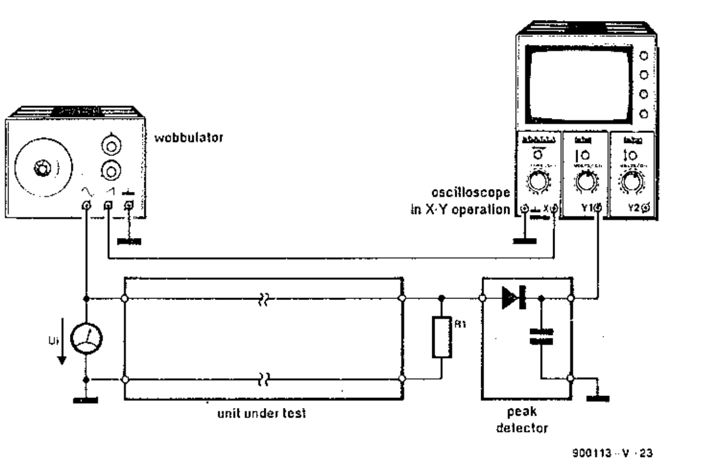

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