sweep generator

Determining the frequency response of an amplifier normally requires a series of carefully conducted test measurements, a large supply of graph paper, and plenty of patience. Wrestling with peak-peak values, RMS voltages, dBs, logarithms etc. can prove to be something of a chore, and it is all too easy to make mistakes which 'distort' the final results. However if one possesses an oscilloscope, there is a way of displaying frequency response curves directly upon its screen – provided one also has the instrument described here, namely a sweep generator.

(L. Köppen)

Sweep generators are not usually part of the basic equipment of amateur electronics enthusiasts, for the simple reason that such an instrument is normally too expensive. However if we are content with an instrument which will provide relative results (which is often more important than the measurement of a quantity with absolute accuracy), then there is no reason why a sweep generator should not be included in the test equipment of every hobbyist.

Why sweep?

What exactly is a sweep generator? The simplest way to answer this question is to look at how one would normally set about measuring the frequency response of an amplifier. The usual measurement set-up is illustrated in figure 1.

The amplifier under test is provided with an input signal from a low frequency sinewave generator. The amplitude of the amplifier output signal is measured on an AC voltmeter. We now ensure that the amplitude of the input signal is held constant, and measure the amplitude of the output signal for a number of different input frequencies. The results are plotted on graph paper, with frequency along the horizontal axis and amplitude (voltage) along the vertical axis. In this way the frequency response of the amplifier is immediately apparent – how flat it is, at what frequency it starts to roll off, etc.

With this arrangement, each time we wish to make a new measurement the frequency of the sinewave generator must be increased by hand. It would of course be much simpler if, in some way, this could be done automatically. This would also allow a continuous increase of the frequency (instead of in discrete steps), thereby ensuring that we are not jumping over small dips or peaks in the response. Thus what is required is a signal whose frequency increases continuously. In other words, a sweep generator.

Figure 2 illustrates how a sweep generator is used to display the frequency response of an amplifier on an oscilloscope.

The sweep generator actually provides two signals: the above described input signal for the amplifier, and a voltage which varies with the frequency of the input signal. The latter signal, designated X, is used to control the horizontal deflection of the oscilloscope (X amplifier). The vertical deflection of the spot is determined by a voltage which is proportional to the amplitude of the amplifier output signal. This is obtained simply by rectifying and smoothing the amplifier output signal. The result of such an arrangement is that the frequency response of the amplifier is displayed directly on the scope screen, with amplitude along the vertical axis, and frequency along the horizontal axis.

Not linear, but logarithmic

As most readers will no doubt know, it is generally the case that a logarithmic scale is used for the frequency axis in such graphs. The question is, how to ensure a logarithmic relationship between the frequency of the sweep generator signal and the external timebase input signal (X). One answer is to increase the frequency of the sweep signal linearly, whilst that of the X signal is increased logarithmically. However a better solution is to let the X voltage increase linearly, and increase the frequency exponentially (with time). In this way there is a logarithmic relationship between frequency and X voltage, whilst the horizontal deflection of the scope will remain constant. This means that the brightness of the trace will also remain constant, and more importantly, affords the possibility of using the (linear) timebase generator of the scope (as not every scope has an X-input).

It should be noted that the vertical axis of the response ought to have a logarithmic scale as well, a facility which is not provided by the circuit described here. Strictly speaking, however, the provision of a logarithmic Y axis is not among the functions of a sweep generator; its job is simply to provide the necessary input signals for the measurement procedure. A suitable circuit (with p.c. board) was published in Elektor, January 1978: the peak programme meter.

Basic circuit

The basic design of the sweep generator is illustrated by the block diagram of figure 3.

An asymmetrical squarewave oscillator is used to trigger a sawtooth generator, which provides the control voltage for the X input of the scope. The X-voltage is also used, via an exponential converter, to control a VCO, resulting in a signal with a frequency exponentially related to the X-voltage. The block diagram is completed by buffers for the various output signals.

The sweep generator has two outputs, the first offers a choice of sinewave or triangle waveforms, whilst the second provides a squarewave. Although triangle and squarewave signals are not generally employed to determine the frequency response of circuits, they are useful in a number of other applications.

The circuit also contains a 'manual' switch, which allows the frequency of the generator to be continuously varied by means of a potentiometer, rather than automatically swept up and down the frequency range.

The circuit in detail

The complete circuit diagram of the sweep generator is shown in figure 4. As can be seen, the circuit contains a number of switches which function as follows:

S1 – sweep inhibit
S2 – sweep/manual
S3 – sinewave/triangle
S4 – frequency range
S5 – output attenuator

A more detailed description of these functions will be dealt with later in the text.

An asymmetrical squarewave oscillator is formed by the circuit round T1 and T2. The output of this oscillator is attenuated by R6 and R7 then limited by diodes D1 and D2 which are connected in 'reverse-parallel'. This signal is then used to trigger the sawtooth generator

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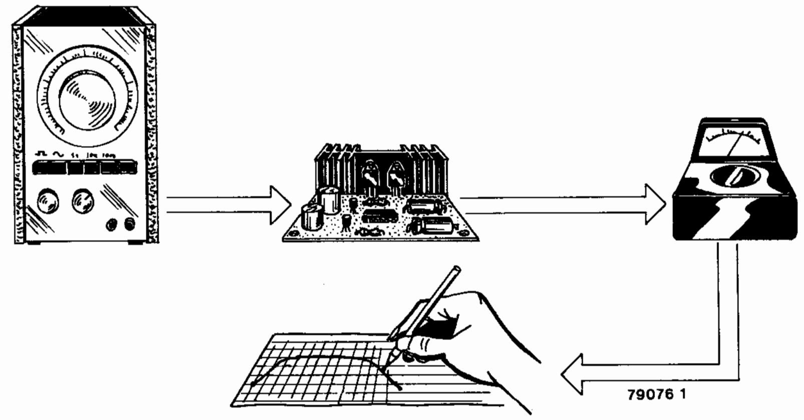

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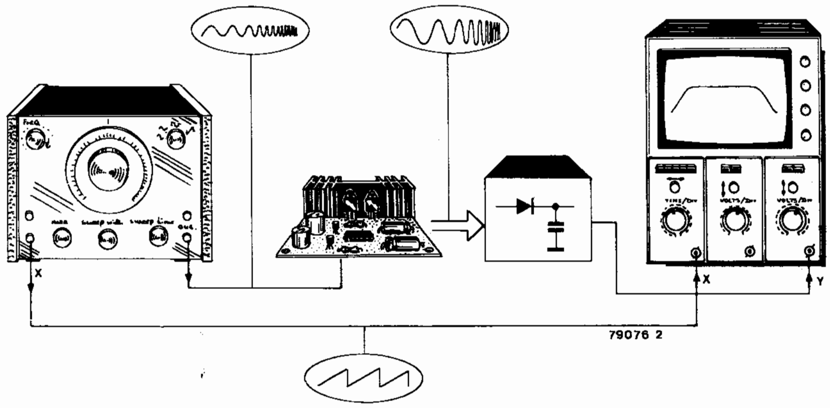

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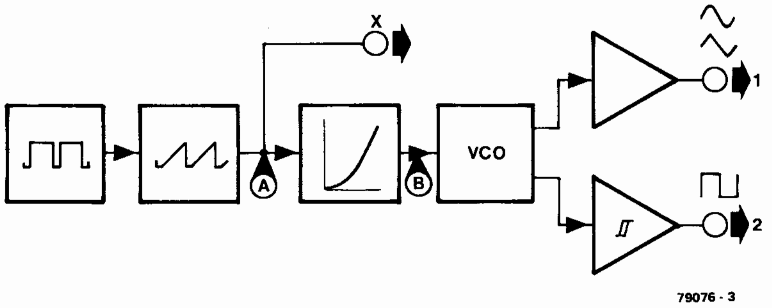

Figure 1. This figure illustrates the basic set up for measuring the frequency response of an amplifier, using a low frequency generator and an AC voltmeter.

Figure 2. With the aid of a sweep generator and an oscilloscope the same measurement can be carried out virtually automatically. The sweep generator provides a sinewave output signal, the frequency of which increases continuously, and a sawtooth signal which is used as an external timebase input for the scope.

Figure 3. Block diagram of the sweep generator. In order to provide a logarithmic frequency scale, the circuit ensures an exponential relationship between the instantaneous value of the sawtooth and the VCO frequency.

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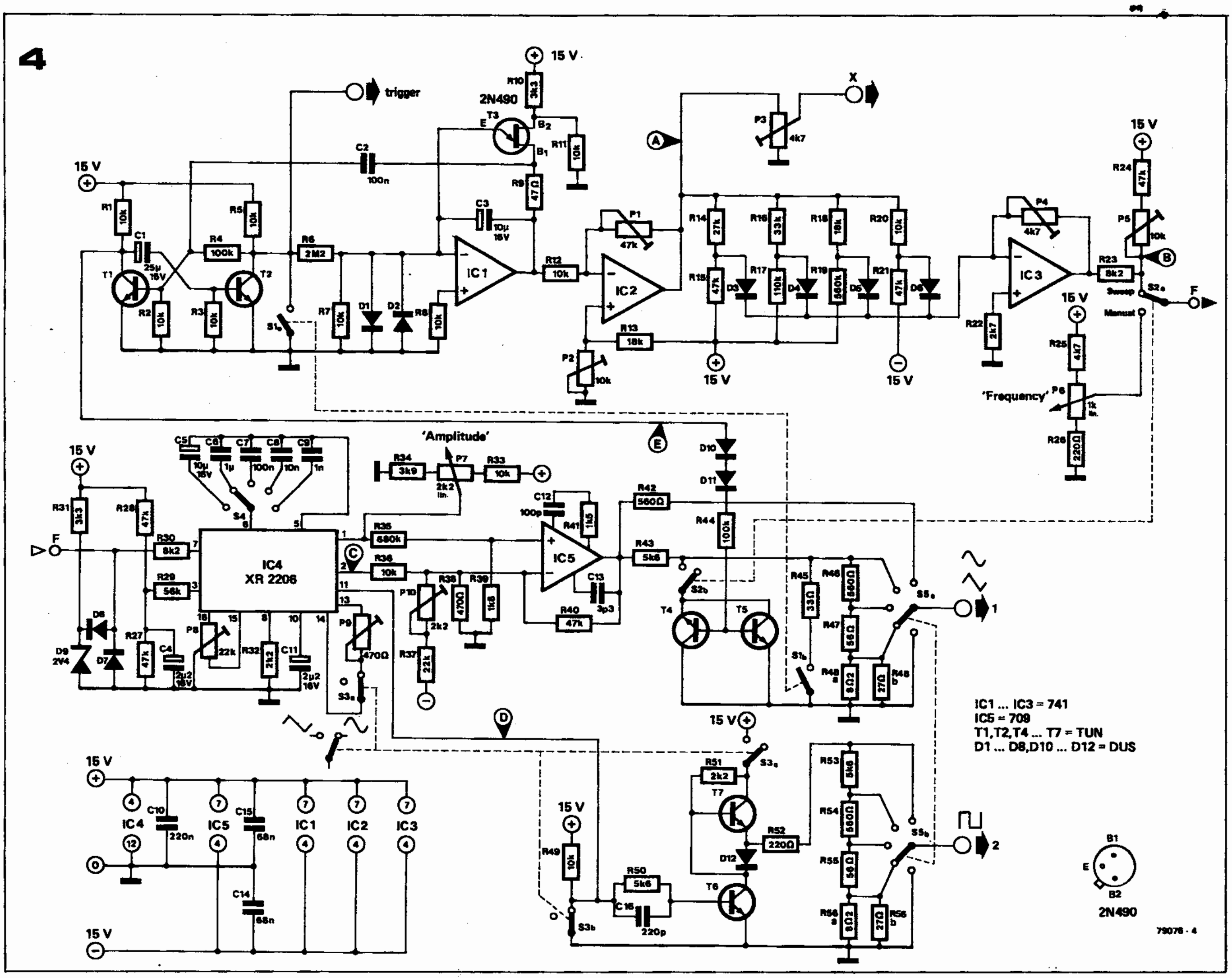

IC1 ... IC3 = 741
IC5 = 709
T1,T2,T4 ... T7 = TUN
D1 ... D8,D10 ... D12 = DUS

Figure 4. Complete circuit diagram of the sweep generator. The exponential converter consists of a diode-resistor matrix.

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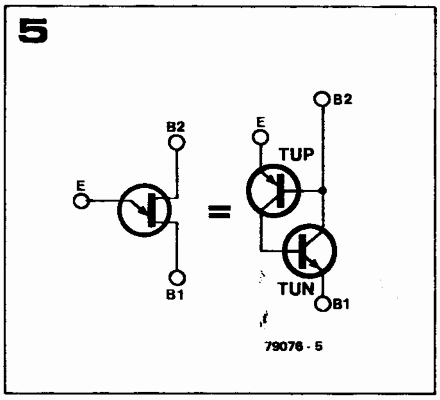

Figure 5. The unijunction transistor for the sawtooth generator can, if desired, be replaced by two separate transistors.

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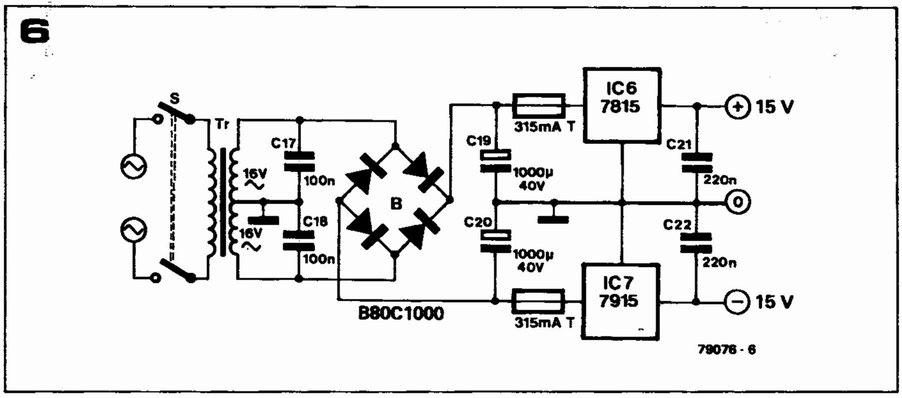

Figure 6. Circuit of a suitable power supply for the sweep generator.

consisting of IC1 and the unijunction transistor (UJT) T3. When the voltage on C3 reaches a certain value, T3 turns on, with the result that the voltage at the output of IC1 ramps negative. The period of the sawtooth is approximately 10 seconds, which may appear rather long. However it is important that the frequency of the sawtooth is much lower than that of the lowest VCO signal. After being amplified and inverted by IC2 the sawtooth waveform is used as the external timebase signal for the scope. The peak-peak value of the voltage at point A is 16 V.

The next step is to derive an exponentially related voltage from this sawtooth, and so this end a diode-resistor matrix, consisting of D3 ... D6 and R14 ... R21 is used. Basically the matrix forms a voltage divider network in which the size of the input voltage (i.e. A) determines which resistors are included in the divider chain. As with all exponential converters, the diode-resistor matrix provides only an approximation to an exponential signal, however the advantage of this arrangment is that it possesses excellent temperature stability.

The output of the matrix is amplified by IC3. The exponential characteristic can be adjusted by means of P4 and P5 — the procedure will be described later in the article. Assuming P4 and P5 are correctly adjusted, a signal which is synchronous with the sawtooth and which increases exponentially with time will be present at point B.

Oscillator

The actual sweep signal is generated by IC4, a function generator type XR 2206. A detailed description of this IC was contained in Elektor 33 (January 1977).

The input of the IC is protected against excessively large voltages by diodes D7 ... D9 and R31.

The IC has two outputs which provide a signal of the same frequency. Depending upon the position of S3, the output at pin 2 (point C) will be a triangle or sinewave, whilst pin 11 (point D) provides a symmetrical squarewave. The range switch, S4, provides five frequency ranges (1-10 Hz, 10-100 Hz, 100-1 kHz, 1-10 kHz and 10-100 kHz). The amplitude of the triangle/sinewave output can be varied by means of potentiometer P7.

With S2 in the 'sweep' position, the oscillator frequency is controlled by the output of the exponential converter. In the manual position, the circuit functions as a conventional function generator, the frequency of which can be adjusted by means of P6.

The sinewave/triangle output is buffered by IC5. This op-amp must be capable of rapidly handling large input signals, therefore a 709 is used, since it has a higher slew rate than the 741 (IC1 ... IC3). The control voltage which determines the amplitude of the sinewave/triangle signal is fed not only to pin 1 of IC4, but also via R35 to the non-inverting input of IC5. This compensates for the effect of the control voltage on the DC component at point C. The buffered sinewave/triangle is fed to a voltage divider. By means of S5 the amplitude of the output signal can be varied in 20 dB steps. The circuit is short-circuit proof in all positions of the switch.

The reverse-parallel connected transistors T4 and T5 form a voltage controlled limiter. When the voltage at point E goes high, T4 and T5 receive base current and conduct on negative and positive half cycles of the waveform respectively, so that the sinewave/triangle is limited to the saturation voltage of these transistors. This step ensures that the signal is suppressed during the flyback of the sawtooth. For this reason the voltage at point E is derived from the squarewave oscillator which triggers the sawtooth generator.

The XR 2206 also provides a squarewave output (from pin 11), which is buffered by the circuit round T6 and T7. Although this circuit looks rather unusual, it is basically a discrete equivalent of the totem-pole output of TTL ICs. Because of the effect of D12, when T6 is turned on the voltage at the base of T7 is lower than that at the emitter, i.e. T7 is turned off. On the other hand, when T6 is turned off, D12 is reverse biased and the base of T7 is at a higher potential than the emitter, so that T7 is turned on.

The squarewave output is also provided with a switchable attenuator, however, unlike the sinewave/triangle output, there is no suppression of the signal during the flyback of the sawtooth, since there is basically little point in using the squarewave signal in the 'sweep' mode.

Trigger output

In addition to the X-output and the two function generator outputs, the circuit is also provided with a trigger output, which can be used if the oscilloscope does not have an external timebase input. The signal at the trigger output remains high for the duration of the sweep, and should thus be fed to the sync input of the scope. The trigger output can also be used for the Z-input of scopes which have such a facility, ensuring that the trace is blanked during flyback of the sawtooth.

S1 is a pushbutton switch, which, as long as it remains depressed, inhibits the sweep. If the button is pressed during a sweep, the cycle is interrupted and the signal at output 1 is suppressed.

S3 switches between sinewave and triangle waveform at output 1. At the same time it also switches the squarewave signal in and out. The squarewave is only present when S3a is in the triangle position. This prevents pulse spikes being superimposed upon the sinewave output because of crosstalk between the two outputs.

Construction

Care is required in the construction of the sweep generator. Of particular importance is the circuit around IC5, since, in order to obtain a high slewrate, this op-amp is somewhat undercompensated. This means that it may well exhibit a tendency to oscillate and to counteract this effect R38 has been included. Capacitors C14 and C15 should be mounted as close to the IC as possible.

For potentiometer P6, used to vary the frequency when the generator is used in the manual mode, it may be advantageous to use a multi-turn type with slow motion drive, thus permitting accurate adjustment.

Should the unijunction transistor prove difficult to obtain in certain areas, the following alternatives are offered: 2N492, 2N1671, 2N2418, 2N2420, 2N2422, and a further possibility is the TIS 43. In addition it is also possible to replace the UJT by two separate transistors as shown in figure 5.

The sweep generator requires a power supply which can provide + and − 15V at 300 mA. A suitable circuit is shown in figure 6 and this can be built on the EPS 9968-5 printed circuit board.

Calibration

The sweep generator has eight preset potentiometers, and before beginning the calibration procedure they should all be set to their mid-positions. The same also holds for the control potentiometers, P6 (frequency) and P7 (amplitude). S5 should be set for minimum attenuation, and S2 to 'manual'. With S3 in the 'triangle' position, there should be both a triangular waveform at output 1 and a squarewave at output 2. With S2 in its alternative position the squarewave should be absent.

By means of P7 it should be possible to vary the amplitude of the triangle waveform by at least a factor of 10. Should this not be the case, then a smaller value should be chosen for R33. Similarly, with the aid of P6 it should be possible to vary the frequency by a factor of 10. If this is not the case, both R25 and R26 should be reduced.

The symmetry of the triangle and sine waveforms can be adjusted by means of potentiometer P8, whilst the distortion factor of the sinewave can be reduced to a minimum by adjusting P9. For both these procedures an oscilloscope is necessary.

Once the sweep generator has been given five minutes to warm up, P10 can be adjusted to give a DC voltage level of 0 V (offset voltage) at output 1 (triangle/sinewave). When setting the amplitude level with P7 this offset voltage should remain at zero volts, however the value of R35 can be altered if it is found that it does vary.

Having set up the function generator and output stages the adjustment of P1 ... P5 will complete the setting-up procedure. The amplitude of the sawtooth at point A should be adjusted to 16 V peak-peak by means of P1, whilst P2 is used to ensure that the sawtooth is symmetrical about 0 V. Should it prove necessary, the sawtooth can be attenuated by P3 before it is fed to the X-input of the scope.

P4 (amplitude) and P5 (DC voltage level) are adjusted such that the exponential voltage at point B varies between + 2.75 V and + 0.54 V. It will be apparent that P5 also influences P4. Once these two potentiometers have been adjusted the sweep generator is ready for use.

The performance of the circuit — particularly in view of the relatively low cost — is excellent. Within the frequency range of 5 Hz to 100 kHz the amplitude of the sweep signal is constant ± 0.25 dB; below 5 Hz the amplitude increases slightly. The frequency characteristic of the generator is also extremely stable, and the zero voltage setting at output 1 exhibits very little temperature drift.

Literature:

Simple Function Generator, Elektor 33, January 1978. ◆