Two-tone generator for testing singlesideband systems

This project is an invaluable test instrument for the radio amateur or serviceman working with SSB transmitters.

WHEN SETTING UP a home-made SSB transmitter (such as one using our Project 725 Polyphase Generator, published in August 1979), testing a transceiver or setting up a homebrew linear amplifier, an appropriate audio signal source is absolutely essential. The most commonly used signal source for this sort of testing is a "two-tone" signal generator. Used in conjunction with even a simple oscilloscope, any single-sideband transmission system can be adjusted for best linearity — and thus, least distortion — eliminating "splatter" which can cause interference to other transmissions nearby. The two-tone generator is also invaluable for determining peak envelope power (PEP) of a transmitter.

The completed project was housed in a convenient 'zippy' box.

Why?

The input-output relationship of a single-sideband transmitter must be reasonably linear or intermodulation will cause distortion products that can extend well outside the SSB channel. The amount of distortion tolerable in an SSB rig is difficult to estimate. Of course, it is important to ensure that products outside the channel are kept as low as possible, but distortion that occurs inside the channel is another matter. Gross distortion must be avoided — but often, changes in distortion level may make very little difference to the perceived transmission quality. Furthermore, in attempting to eliminate some small vestige of distortion inside the passband, other parameters may be degraded. Most likely to suffer will be efficiency, with an associated increase in current flowing in the output stage causing increased thermal dissipation, and possibly a shortening of the output device's life-span.

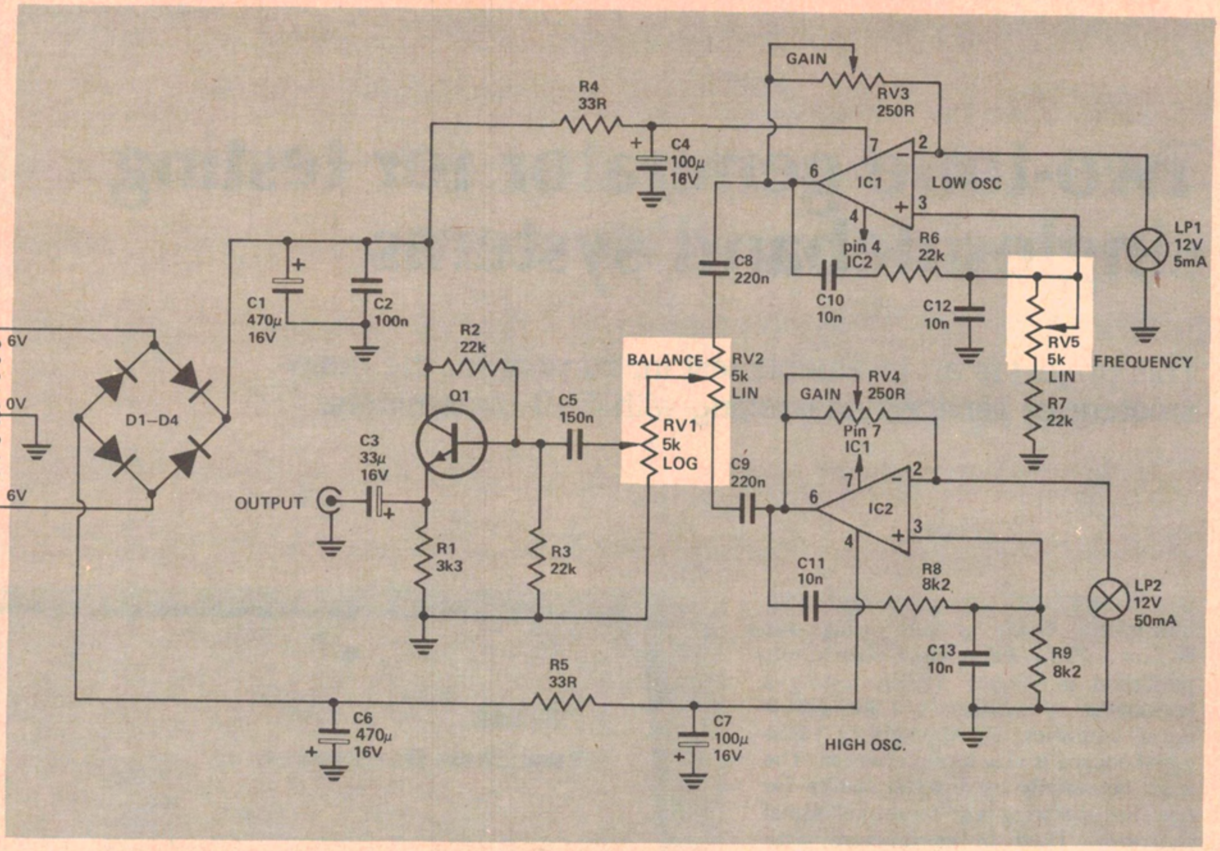
The major causes of distortion in output stages are clipping and cross-over distortion. Clipping occurs at high power levels. An increasing input voltage will eventually overdrive the amplifier, when it is not possible for the output voltage (or current) to follow the input accurately. It is easily cured by ensuring that the output stage is not overdriven. A two-tone generator is used to establish the maximum input level that will not produce clipping.

Cross-over distortion in push-pull designs is related to bias adjustment and becomes the dominant form of distortion at low signal levels. The cure is not as simple as is the cure for clipping. The output stage idle current can be increased but this will decrease efficiency. Often, filtering is used to reduce distortion products due to cross-over and here again, the two-tone generator is used to get an idea of the amount of cross-over distortion present.

The test generator is used with a CRO connected to the output of the transmitter, either directly or via an RF probe. The generator is connected to the microphone input and the resultant wave shape observed on the CRO. The presence of distortion products will change the waveform so that a clean sine wave shape will indicate a good clean transmitter. Increasing the input level until the output 'flattens' on the peaks will indicate the input level at which clipping occurs (this is called "flat-topping").

The generator

The generator simply mixes two sine waves together so that the transmitter is modulated by the beat frequency of the two tones. It is important that the tones are not harmonically related and that one of the tones can be adjusted slightly in frequency to make it easier for inexpensive CROs to sync on the ▶



output waveform. A balance control has been fitted to the unit so that the level of the two tones can be made equal if filtering in the transmitter audio preamplifier attenuates one signal more than the other.

The sine wave oscillators consist of op-amps in a Wien Bridge circuit. (See 'Lab Notes', Dec. '79). The frequency of the basic oscillator is given by the equation:

$$f = \frac{1}{2\pi R8\ C11}\ \text{Hz. Where R8=R9, and C11=C13.}$$

This gives frequencies of 1850 Hz for the fixed oscillator and 600 to 700 Hz for the variable frequency oscillator.

The problem with this type of circuit is that the gain must be closely maintained or the sine wave will be clipped severely. The necessary gain stability is achieved with the use of a light bulb in the negative feedback loop. The resistance of the light bulb varies with temperature,. increasing with increasing temperature. If the oscillator amplitude were to increase, the larger current through the filament would increase its temperature, increasing its resistance,bringing about a rise in the amount of negative feedback and a consequent decrease in oscillator amplitude. The circuit works very well and once the oscillators are set up, they will operate quite reliably. The light bulb used was a standard 12 volt "lilliput" bezel globe rated at 50 mA. A variety of globes can be used, although the value of the feedback presets might have to be changed, if the bulb chosen has a very different current rating from the one specified.

The outputs of the two oscillators are fed to either side of RV2 which serves as the 'balance' pot, and then via RV1 to an emitter-follower stage around Q1. This provides the generator with the necessary low output impedance. If it is found that the output voltages are unnecessarily high a series resistor (≈ 47k) can be placed between the wiper of RV2 and the 'top' of RV1 – replace the link between the wiper of RV2 and the pc board with the resistor.

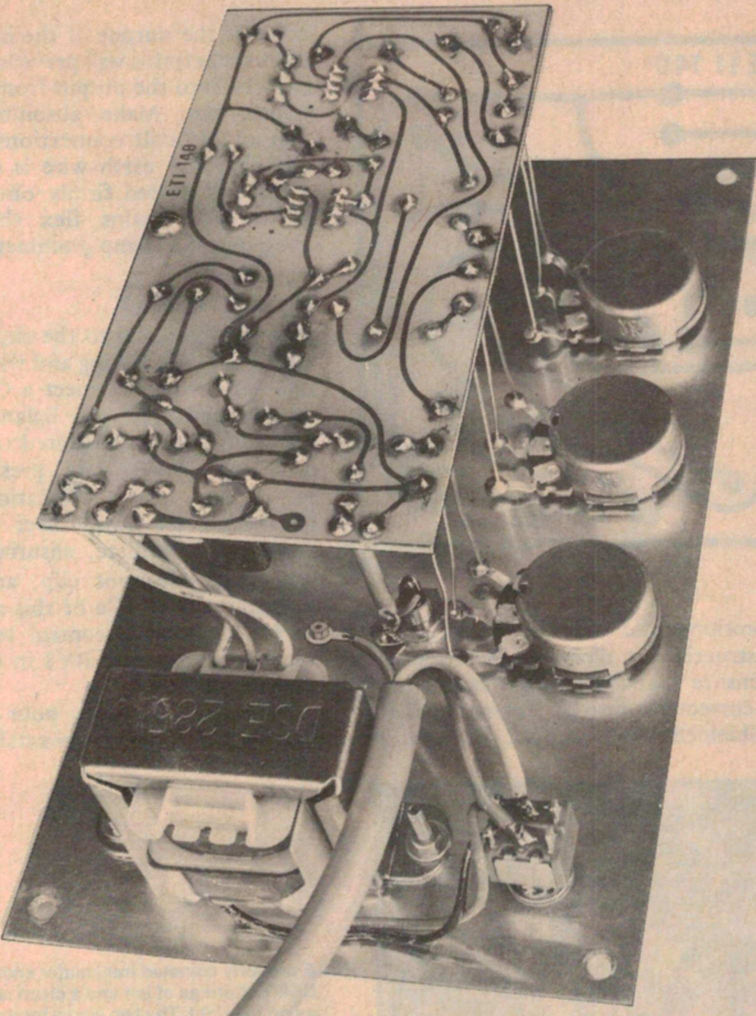
HOW IT WORKS

IC1 and IC2 form Wien Bridge oscillators at the frequency determined by C10, C11, C12 and C13, R6, R7, R8, R9 and RV5. The potential dividers formed by RV3, RV4 and the two light bulbs maintain the amount of overall gain to prevent distortion. Capacitors C8 and C9 couple the outputs of the oscillators to the balance pot RV2. Capacitor C5 couples the output of the volume control to Q1. The bias for this stage is determined by the potential divider R2, R3. The output is taken across R1 via the 33µ tantalum capacitor. The power supply is constructed on the same printed circuit board, diode D1 to D4 forming a full wave bridge rectifier, C1 and C6 being smoothing capacitors.

Construction

The construction is reasonably simple since it is mostly confined to the pc board. The order the components are placed on the board is not really critical, but it is probably wise to leave the ICs until last as they are the most difficult to unsolder should they be accidentally overheated while soldering other components around them. The light globes are soldered onto the pc board by first soldering wires to the globe. Short lengths of wire cut from the resistors already on the board are ideal for this. Care must be taken not to overheat the globe when soldering to the bottom connection, as the bulb is likely to unsolder itself internally with the heat applied from the soldering iron.

The prototype was constructed in a plastic 'zippy' box but any suitable ▶



View of the internal construction showing placement of the major components and wiring to the potentiometers. The mains earth lead should be grounded to the front panel. Use a cable clamp where this lead enters the case.

PARTS LIST — ETI 149

Resistors

R1	3k3
R2,3,6,7	22k
R4,R5	33R
R8,R9	8k2

Potentiometers

RV1	5k log
RV2,RV5	5k lin
RV3,RV4	250 ohm vertical mounting mini trimpots

Capacitors

C1,C6	470u, 16V electro
C2	100n greencap
C3	33u, 16V tantalum
C4,C7	100u, 16V electro
C5	150n greencap
C8,C9	220n greencap
C10,11,12,13	10n greencap

Semiconductors

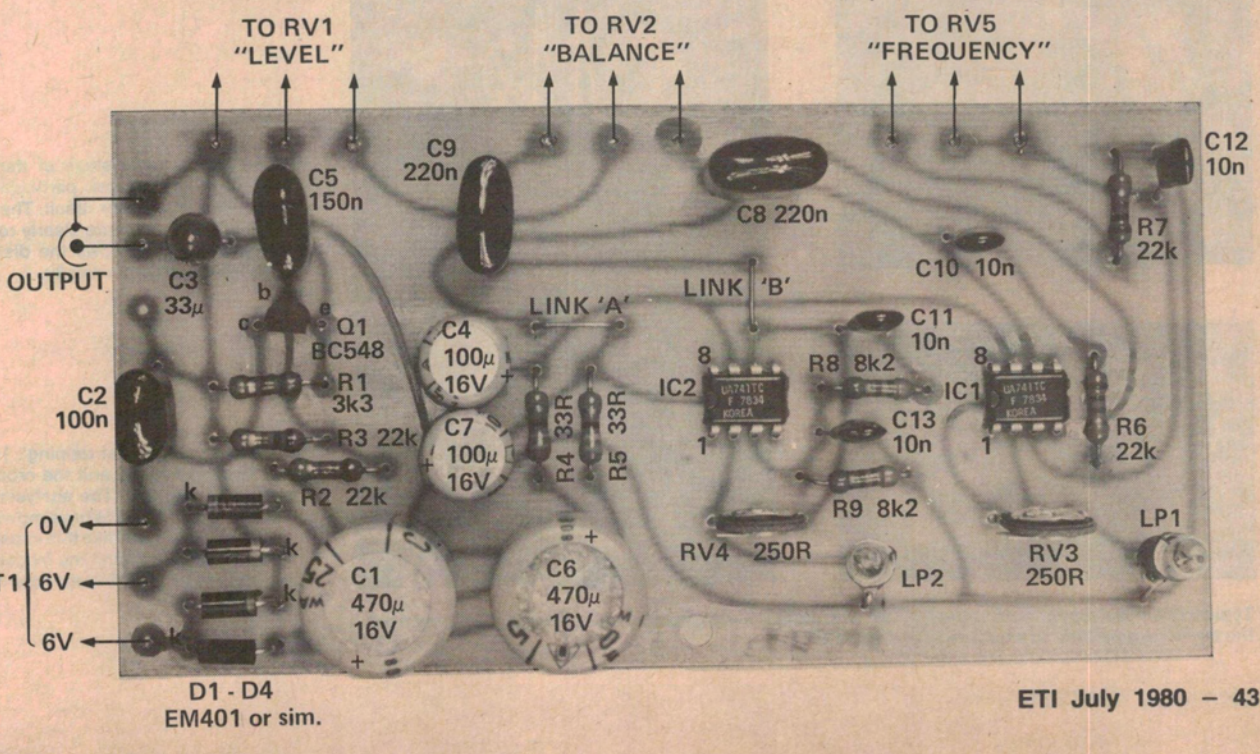
Q1	BC548,BC108 or similar
IC1,IC2	741 op-amp
D1-D4	EM401, 1N4001 or sim.

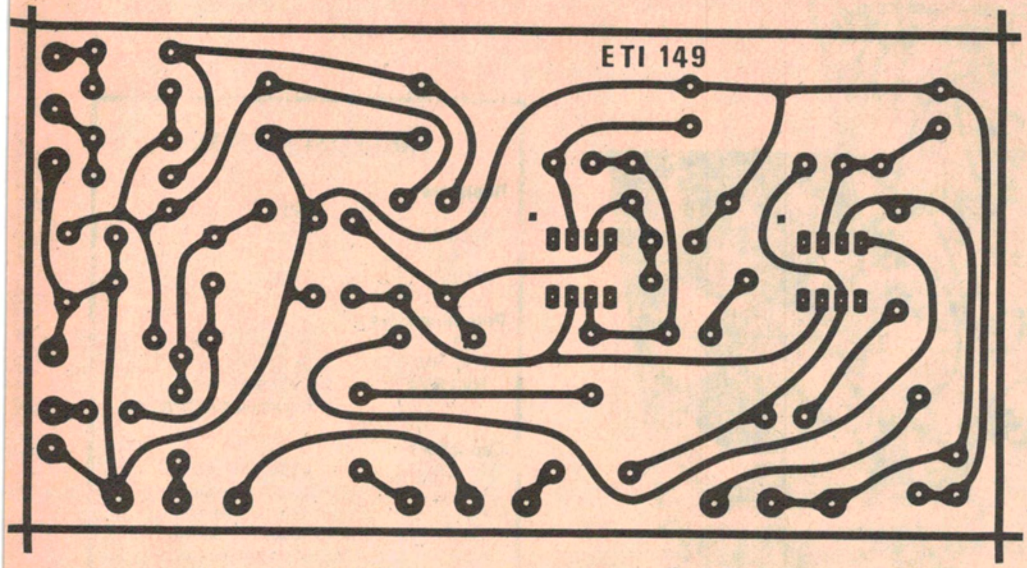
Miscellaneous

LP1,LP2	15 V/50 mA light bulbs
T1	6.3 - 0 - 6.3 V, 150 mA transformer (M-2851 or similar).
SW1	DPST 240 Vac switch

RCA phono output socket; zippy box — 200 x 115 x 60 mm; ETI-149 pc board; three knobs; Scotchcal front panel (see "Shoparound" this issue); power cable, cable clamp and plug.

Component overlay for the printed circuit board.





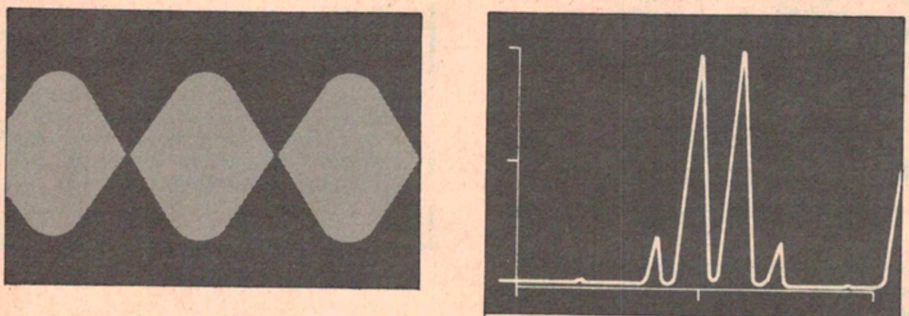
sized box could be used. The printed circuit board was mounted onto the front panel by one bracket bolted to the rear of the board (see photo) and the wire connections to the potentiometers. If this method of construction is chosen it is necessary to ensure that the pots are mounted in the correct position on the front panel.

Shielded cable should be used to connect the output of the board to the RCA socket; this will prevent hum being induced into the output from the power transformer. Make absolutely certain that all 240 volt connections are secure and that the earth wire is soldered to a lug and bolted firmly onto the front panel. The mains flex should enter the case via a clamp grommet.

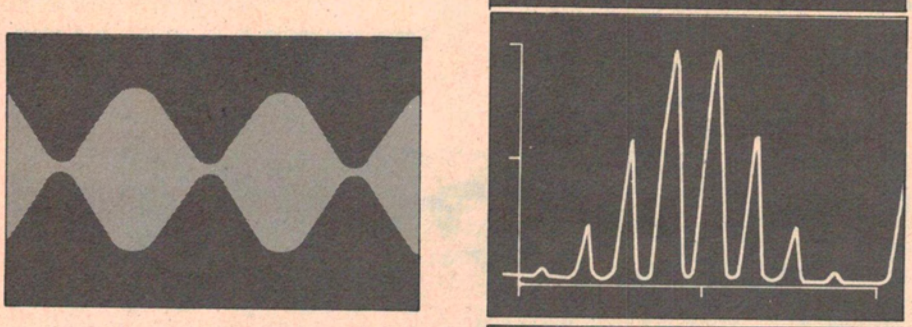
Powering up

Before connecting to the supply, check all the 240 Vac wiring and the pc board. If all is correct, connect a CRO to the output and turn the balance control fully to the side connected to the fixed oscillator. Adjust the preset control RV4 so that oscillation starts. Determine the range over which the circuit will oscillate, ensuring that the waveform does not clip, and set the preset in the middle of this range. Now wind the balance control to its other extreme and adjust RV3 in exactly the same way.

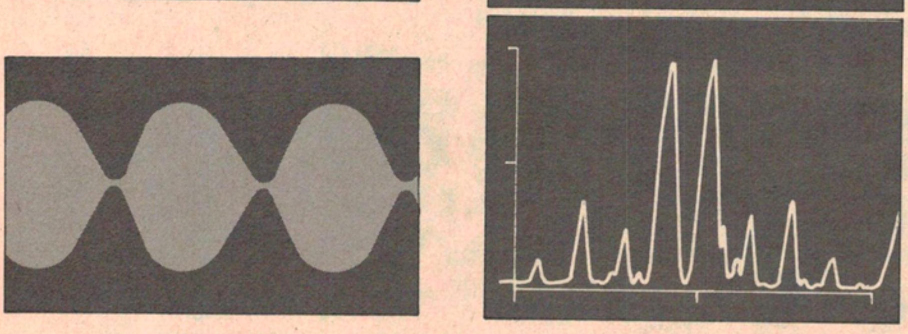
That's it! And may your extraneous sidebands be vanishingly small. ●



◀ A properly adjusted transmitter should produce a CRO pattern as at left and a clean analyser trace, as on the right. The two signal tones predominate and distortion products (the two small 'pips') are well down. Note the clean 'crossing points' on the CRO display.



◀ If the bias on one stage of the linear amplifier system is set too low, particularly the PA bias, these sort of patterns result. The crossing points on the CRO pattern are clearly rounded while the analyser display shows the distortion products have increased dramatically.



◀ A classic case of 'flat topping'. The CRO display has flattened peaks and the crossing points are obviously rounded. The analyser display shows the distortion products have moved away from the main signal. A signal like this causes 'splatter' well away from the transmitting frequency. In general, it is caused by overdriving linear amplifier stages.

Typical oscilloscope patterns you will obtain with corresponding spectrum analyser displays, when using the two-tone generator to adjust an SSB transmitter.