William P. Smith K3LF
R.D. #2
Cold Spring Creamery Road
Doylestown PA 18901

The $50 Sweeper

—build this audio function generator and sweep your troubles away

One of my favorite aspects of ham radio is audio circuitry, and I am constantly constructing amplifiers, filters, and other devices which operate within the audio spectrum. In order to evaluate my projects, I built the swept function generator described here to use in conjunction with my oscilloscope.

The generator features a frequency range of .05 Hz to 300 kHz, digital frequency display, and a sweep range of 1000:1 or better. The unit produces sine, triangle, and square waves as well as left- or right-sloped ramps and pulses with an adjustable duty cycle of 1% to 99%. The outputs may be amplitude- or frequency-modulated by an external signal and adjusted in amplitude from six volts peak-to-peak down to millivolts. The sine, triangle, and square waves may be swept in frequency by a built-in linear sweep circuit or by an external signal. The cost is in the $50.00 range if you have a moderately stocked junk box. The majority of the parts are stocked by Radio Shack. About half of the cost is in the digital frequency display, which may be easily replaced with a frequency counter or an analog scale.

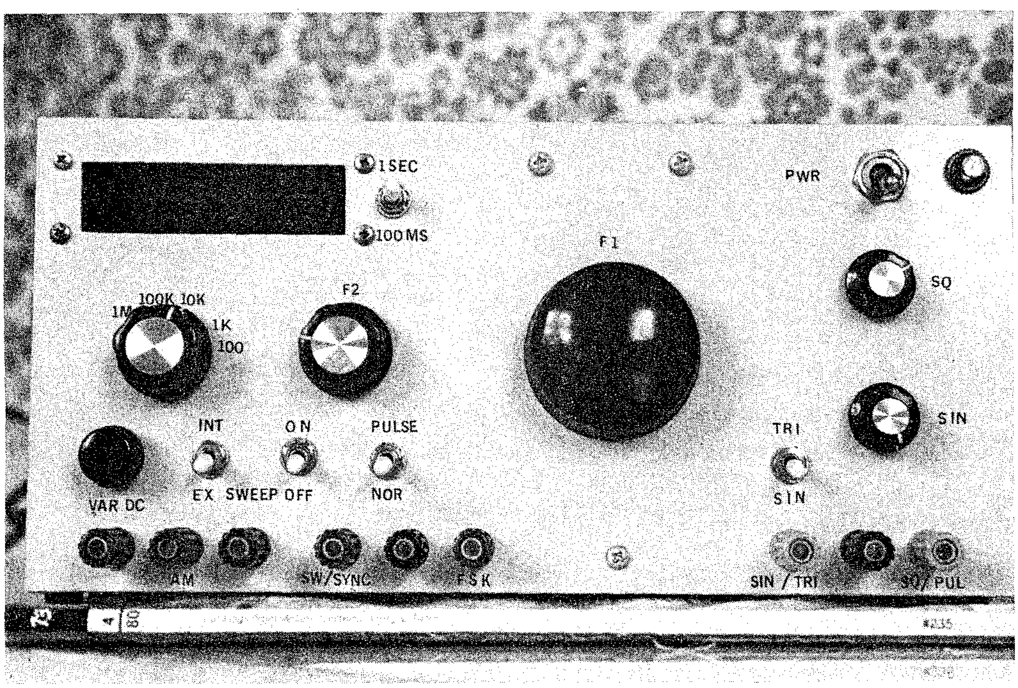

Photo A. The completed swept function generator. The knob labeled F1 is the primary frequency control and is mounted on a 3:1 gear drive. The SIN/TRI output jack also provides a ramp function. All unlabeled jacks are grounds, except the jack, far left, which is the variable dc output.

The entire unit consists of the function generator circuits, the sweep circuits, the digital display circuits, and the power supply. The function generator circuits actually contain two function generators, designated the primary and secondary, and labeled F1 and F2 in the picture of the front panel (Photo A). The two generators may be set independently of each other and it is possible to shift between the two merely by changing the logic level at the FSK jack. The amplitude of the output is absolutely constant from the lowest frequency up to 300 kHz with a usable signal generated up to about 1 MHz. Distortion of the sine wave is adjustable and quite good at approximately .5% THD.

Construction

The heart of the function generator is an XR 2206 IC. I purchased my chip from Jameco Electronics, 1021 Howard Ave., San Carlos CA 94070. Be sure to ask for the spec sheet; the additional 25 cents is well worth the price. I used the manufacturer's recommendations on wiring the 2206 except for several modifications that are peculiar to my function generator. If you do not want to build the sweep circuit, then just leave those components off of the circuit board; there are no components that are used for both the function generator and the sweep circuits.

I used ¼-Watt, 5% resistors except for R12, which is not critical but should be at least 1 Watt. Capacitors C1 through C5 are frequency-determining components and should be 5% or better, and for best results should be made of some stable material such as polystyrene. Other types of capacitors could be substituted, but the generator will be slightly less stable. Wherever possible, I have tried to provide large pads on the circuit board to accommodate capacitors of different sizes.

Trimmer pots R1, R2, R3, R6, R7, and R8 all are mounted on the PC board. I have provided space on the circuit board so that either the stand-up or the lay-down type of trimmer may be used. It seems that I always have the wrong type when building a project on someone else's circuit board, so I have allowed for both types (prospective authors please take note). Front-panel pots R4 and R5 are the other frequency-determining components. During normal use, R4 is the main frequency control, and I have mounted mine using a 3:1 gear drive so that the frequency can be varied in small increments. Potentiometer R5 is used to set the frequency of the secondary function generator and to adjust the shape of the pulse and ramp functions. I found it sufficient to mount R5 directly on the front panel without a gear drive.

The function generator may be swept in frequency by applying a varying voltage to R5. For maximum frequency sweep, 1000:1 or better, this voltage should vary from 0 V to +3 V, with the highest frequency being generated at 0 V. I have arranged the front-panel

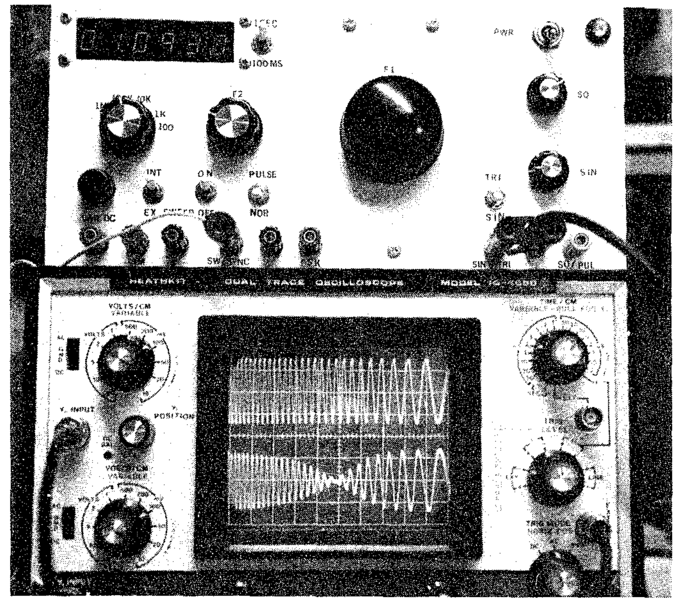

Photo B. The swept function generator in operation. The top trace is the output of the generator in the sweep mode. The bottom trace is the same signal after processing in a home-brew notch filter. The notch filter has a design frequency of 1100 Hz. Note the digital display showing 1,093 Hz which will correspond to the center of the scope face. The actual sweep here is about 20 Hz to 2200 Hz.

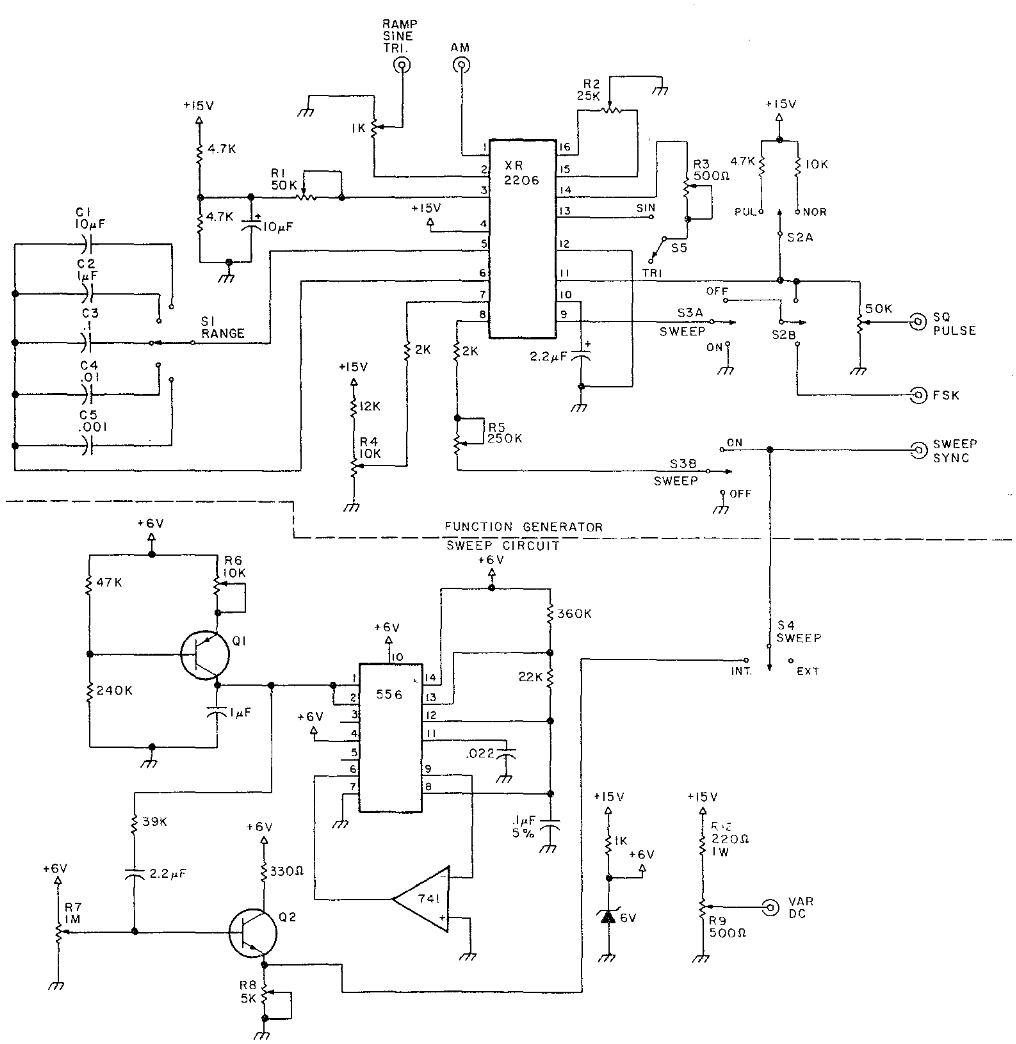

Fig. 1. Schematic of function generator and sweep generator.

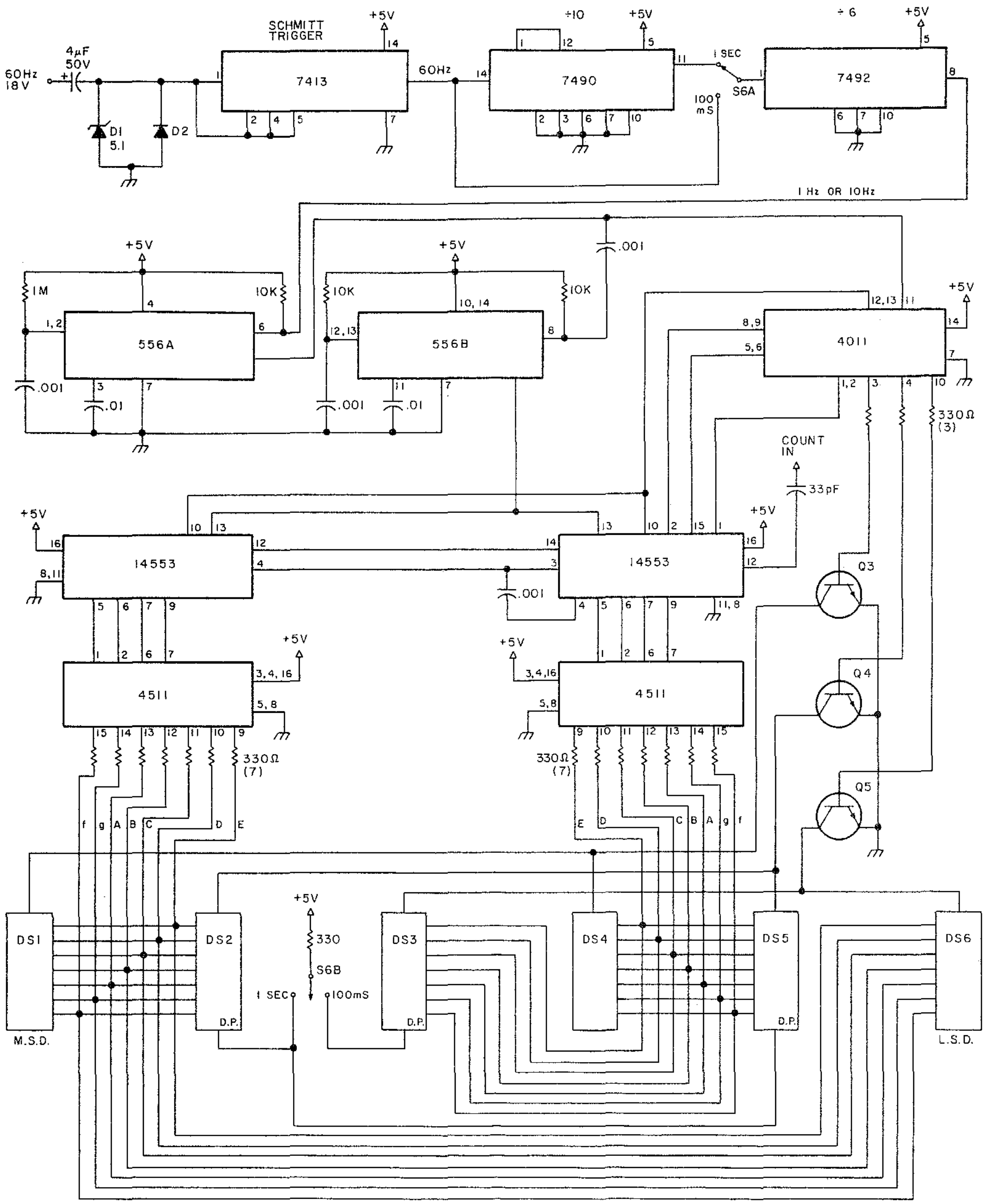

Fig. 2. Schematic of digital frequency display.

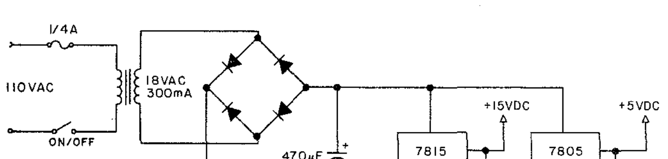

Fig. 3. Power supply. C6 and C7 are 2.2-uF tantalum and are mounted on the circuit board. All other components are mounted on the chassis.

switches so that the function generator may be swept or frequency-modulated by applying a varying voltage to the sweep/sync jack from an external source or from internal circuitry. The internal sweep circuit is a linear ramp generator which provides a 3-V ramp at a frequency which allows one sweep to fill my scope screen when set to 2 ms/cm. When the internal sweep circuit is used, the ramp signal is applied to the sweep/sync jack so that it may be used to trigger your scope.

Operation of the sweep circuit is not overly complex. One half of the 556 dual timer is wired as a monostable multivibrator which is used for a timebase. The 741 op amp inverts the output of the multivibrator to provide a good trigger signal. The actual ramp is generated by the other half of the 556 and the two transistors. Transistor Q1 is a 2N4250 or similar and provides a constant current source to capacitor C6. This constant current allows C6 to charge linearly. The other half of the 556 timer acts as a switch which grounds the positive side of C6, when triggered by the op amp. The voltage across C6 almost instantly goes to zero and then begins to recharge. Transistor Q2 (a 2N2222) is a buffer amplifier. By adjusting the dc bias on this transistor, the amplitude and position of the ramp relative to ground may be precisely set. The output of this emitter-follower type circuit is the final sweep signal.

The digital frequency display is a multiplexed unit and is based on the Radio Shack three-digit BCD counter IC, part 276-2489. The entire display was point-to-point wired on a multipurpose 22-pin edge connector circuit board which will just accommodate the 9 ICs and three 2N2222 transistors. The timebase is derived from the 60-cycle line. I have found the accuracy to be quite good at audio frequencies, often showing the same frequency as my lab grade counter, up through 50 kHz or so. Even at much higher frequencies, the difference is usually under 100 Hz and the error will always be on the low side. The frequency generated by the function generator is sampled at pin 11 of the XR 2206 and is coupled to the digital display through a 33 pF capacitor. This signal is then counted and displayed by the two sets of 14553 counter and 4511 driver ICs.

The wiring of the LED displays is a little unusual and requires an explanation. If the counter is placed in the 100-ms timebase position, it will count and display 1/10 of the actual frequency being generated, so that 4552 Hz would appear as 455. I found this to be distracting, so I added another LED display in the "ones" position and set it to display a

"0". Now the frequency display would appear as 4550. In order to get the newly-added display to have the same brightness as the other digits, I wired it as if it were in the "millionth" position. There is no leading-zero blanking, so the new digit will always show a zero unless a frequency of one MHz or higher is counted. In the one-second timebase mode, this newly-added digit will appear in the "tenths" position and will be zero unless a frequency of 100 kHz or higher is counted. In this timebase, the display would appear as 4,552.0. The decimal points are wired to the timebase switch so they will always correctly separate the hundredths and thousandths digits.

The digital display circuit is set up for common-cathode displays with right-hand decimal points. Maximum current should be limited to about 25 mA per segment. I used Radio Shack 276-1644 displays but would recommend some of the multiple-digit, multiplexed units such as those sold by Digi-Key, Inc.

The timebase and control circuits for the display are fairly straightforward. A 60-cycle signal is taken off the low voltage side of the power transformer. Diode D2 and zener D1 limit the voltage excursions to −0.7 V and ±5.1 V. This 60-cycle signal is applied to a Schmitt trigger to produce an accurate square wave, and then passes through the 7492 IC wired to divide by six. The resulting 10-Hz square wave triggers the two one-shot multivibrators which form the latch and counter reset pulses. In the one-second timebase, the 60-Hz signal is divided by ten in the 7490 IC before going through the 7492, so that a 1-Hz square wave is applied to the one-shots. Again, this is a surprisingly accurate system, and I have been very pleased with the results.

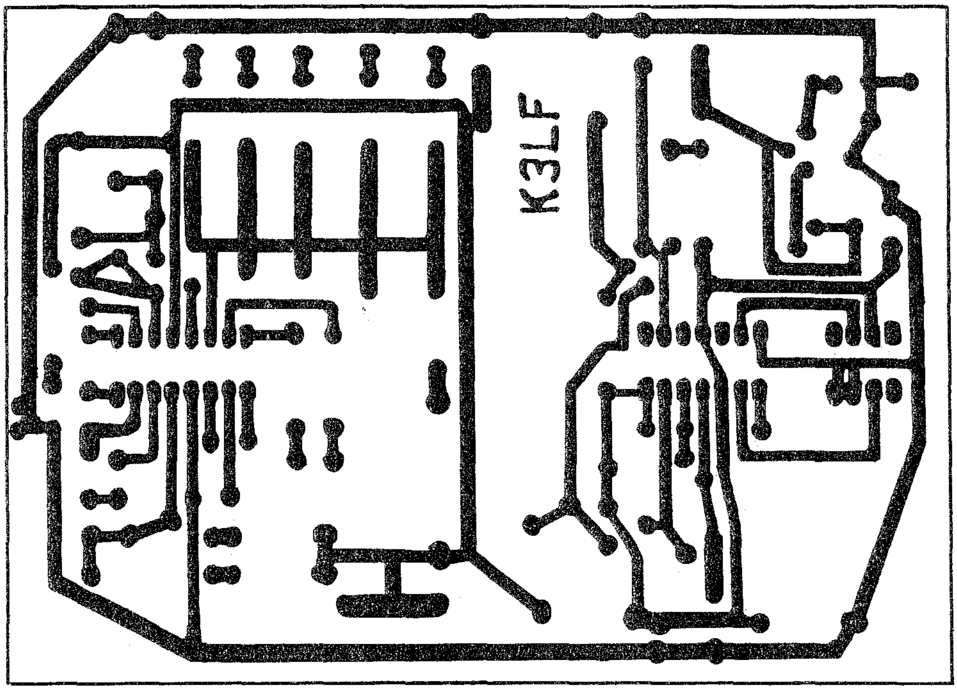

Fig. 4. PC board layout.

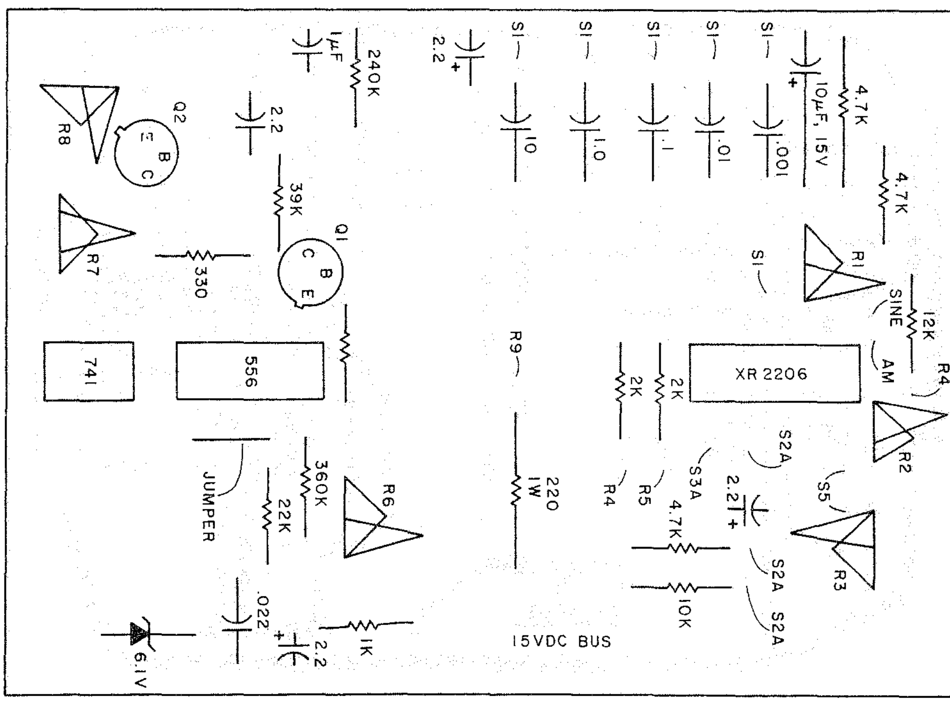

Fig. 5. PC board component location.

The power supply is fairly conventional, using an 18- or 24-V ac transformer, a bridge rectifier, and two regulators, a 15-volt and a 5-volt. If you use a 24-V ac transformer, be sure you do not exceed the maximum voltage which may be applied to the regulators; mine were rated for 35 V dc. All of the power supply components were mounted on the chassis. Note that a 2-wire power cord is used so that the chassis ground is floating and is not connected to the house wiring ground. This allows the function generator ground to be floating and set in relation to other pieces of test gear.

Calibration and Operation

Calibration is not difficult, but does require a dc-coupled oscilloscope. The function generator circuit has three adjustments. Trimmer R1 adjusts the amplitude of the signal with a maximum of six volts for the triangle waveform. Symmetry is adjusted by R2, and R3 adjusts distortion of the sine wave and may be replaced with a 200-Ohm resistor with fairly good results. The three adjustments will interact to some degree; the object is to maximize amplitude and minimize distortion. The sweep circuit is adjusted using R6, R7, and R8. The collector of Q1 should be monitored while adjusting R6, which should be set to a position giving the longest ramp. Too little resistance here will make the ramp generator operate at twice the trigger frequency. With an oscilloscope connected to the output of the sweep circuit, adjust R7 so that the ramp just touches the 0-volt baseline. The amplitude of the ramp is adjusted by R8 to a value of three volts p-p. There is some interaction between R7 and R8, and these adjustments are somewhat critical—so be patient.

Operation of the swept function generator should be fairly obvious, but here are some helpful hints. When operating in the sweep mode, S3 should be placed in the ON position and S4 placed in INT. This will apply the ramp signal from the sweep circuit to the function generator and to the sweep/sync output jack for synchronizing or triggering your oscilloscope. You will find the signal appears to sweep from right to left as the lower frequencies are to the right. If S4 is placed in the EXT position, then an external device may be used to sweep or frequency-modulate the function generator. Whenever S3 is ON, the average frequency will be controlled by R5 and the range switch.

To determine the range of frequencies actually being swept, place the digital frequency display in the one-second timebase mode. The displayed frequency will be very close to half of the peak frequency and 500 times the lowest frequency. I have found this to be a very handy phenomenon. If I am looking at the response of a notch filter and want to know at what frequency the notch occurs, I can adjust R5 until the notch is at the center of my scope. At that point, the frequency displayed on the digital readout will be the frequency of the notch. If I want to apply a swept signal of 10 Hz to 10,000 Hz to some piece of equipment, then I merely adjust R5 until the display shows 5,000 Hz and I will be right on target.

When operating the generator with the sweep turned off and S2 in the NOR (normal) position, the secondary function generator may be activated by grounding the FSK jack. The frequency of the secondary generator is controlled by R5 (the primary generator is controlled by R4).

One last item: Any amplitude-modulating signal must have the same dc bias as the output. Potentiometer R9 has been included to provide an adjustable dc reference voltage. The 220-Ohm resistor, R12, limits the current if the VAR dc jack is grounded.

I have had my function generator in use for about a year and have been very happy with its performance. In the future, I hope to build an interface device so that the function generator can be controlled by my KIM-1 micro via the sweep and FSK inputs. This would probably open the door to all sorts of neat applications. I hope you enjoy this versatile instrument as much as I have. ■