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3. **EXPONENTIAL CONVERTERS:** -by Terry Mikulic

This paper won't deal with the actual mechanics of the antilog function. The antilog, or exponential, volt-ampere relationship of the silicon bipolar junction transistor is well documented elsewhere. Rather, I will be describing practical circuits for making use of this function.

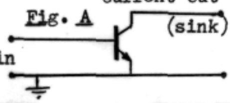


Fig. A

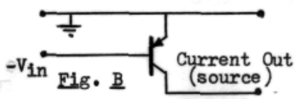


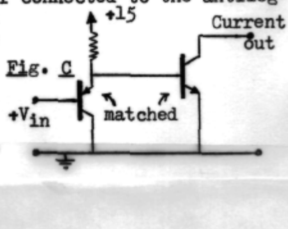
Fig. B

The basic exponential converter is shown in figs. A and B. Surprised? This is all there is to it. Several things must be assumed first though. The transistors must have high D.C. gain (250 or higher), and they must be fed from a low impedance source so base currents won't cause errors. The transistors also must have low collector cutoff current (less than 10 nA).

The input to output relationship of the device can be stated like this: A specific change in input voltage will produce a ratio change in output current, no matter what the value of the initial output current is. Circuit conditions for fig. A are as follows: the transistor needs a certain amount of positive input voltage, say 550 mV, which will produce an initial amount of output current, somewhere around 1 uA. Then, adding or subtracting a specific amount of voltage (at 25°C, about 18 mV) to or from the 550 mV, the output current will be doubled or halved, in that order.

Both voltage values are temperature sensitive, however. The voltage needed to produce an initial specific value of output current has a negative temperature coefficient of -0.3%/°C. The other voltage, which can be called the scale factor, has a temperature coefficient of +0.3%/°C. It has a value at room temperature of typically 18 mV. The initial positive voltage is best compensated with another transistor. A complementary polarity emitter follower connected to the antilog transistor is shown in fig. C. Assume that the input to the emitter follower is at 0V, the transistors are matched, and the gain of the transistors is high enough so that the base currents can be ignored. The collector current of any one transistor will be the same as it's emitter current. Therefore, because the emitter to base voltages of the transistors are the same, the collector currents of the two

Fig. C



transistors are the same. Changes of emitter to base voltage due to temperature changes in one transistor are countered by the same changes in the other transistor. Applying positive or negative voltages of intervals of 18 mV will produce changes in the output current by factors of two. A linear current controlled oscillator connected to the output will produce pitch changes of octaves.

The industry standard for voltage controlled oscillators is one volt into 100k Ohms for a pitch change of an octave. Fig. D describes a circuit which adds all control voltages and reduces a 1 Volt input to 18 mV. It also provides a means of temperature compensating the scale factor, which cannot be compensated with another transistor like the initial forward base voltage. It provides a current source, which must be returned to a point more negative of the emitter of the antilog transistor. This circuit is very accurate over a wide range.

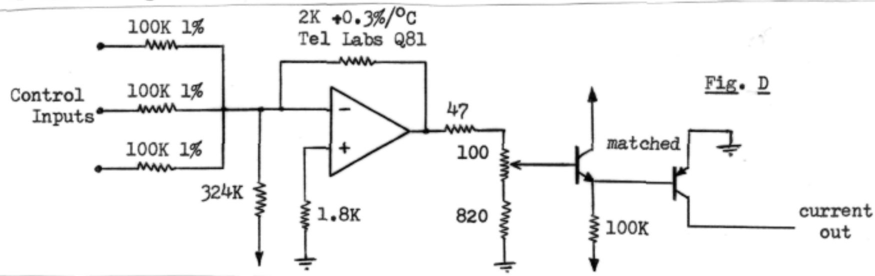


Fig. D

Accuracy at low collector currents is limited by the collector leakage current of the antilog transistor. A transistor selected for low leakage will extend the range. Accuracy at high collector currents is limited by the bulk emitter resistance of the antilog transistor. It can be imagined as the emitter being connected to ground through a resistor of, say 10 ohms. With currents greater than about 100 µA, a voltage drop is produced across the resistance, which reduces the emitter to base voltage of the transistor, thereby producing less collector current than desired. The solution is to provide a positive voltage proportional to the output current and add it with the control voltages, thereby increasing the emitter to base voltage to counter the voltage drop in the emitter.

Fig. E describes a circuit which compensates for emitter resistance. The H.F. track. is adjusted for linear oscillator tracking at high frequencies.

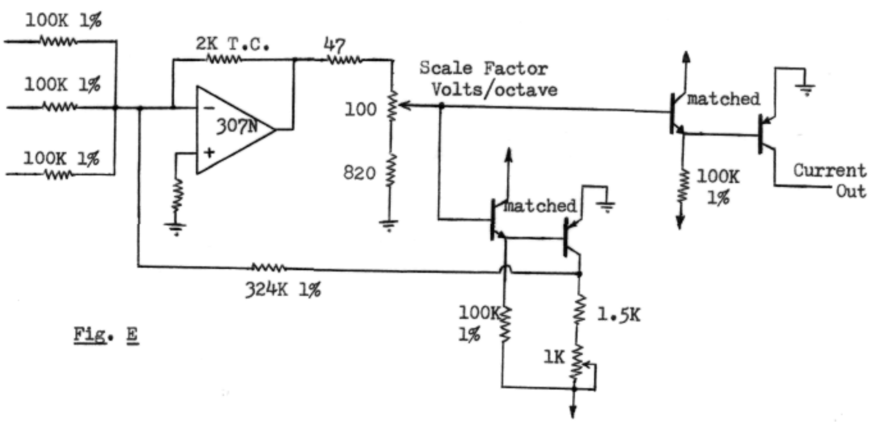


Fig. E

Fig. F is a complementary circuit which provides a current sink, rather than a current source. The circuitry connected to the output must be connected to a positive potential, or it can be grounded.

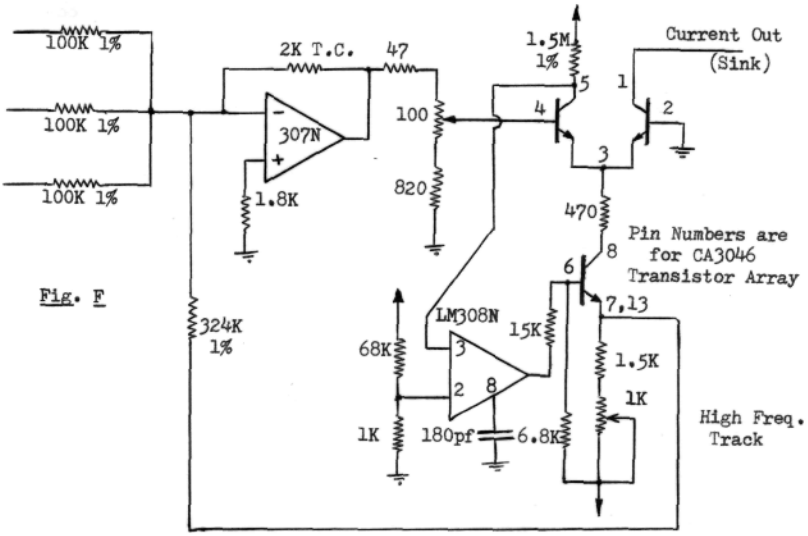
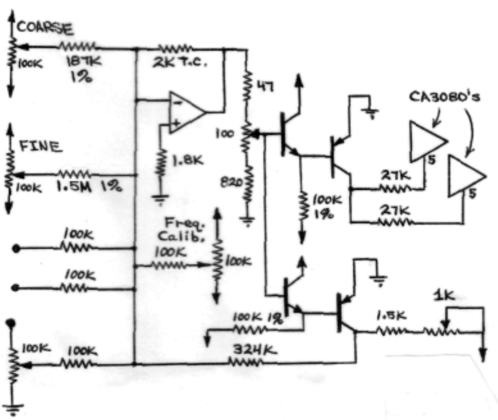
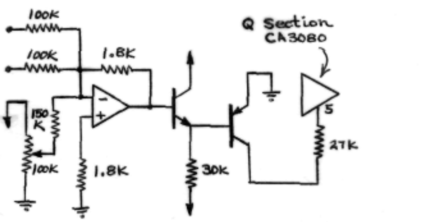


Fig. F

Note: If you need a value of output current different from the current levels developed by the exponential converters in Figs. E and F, connect a resistor to the control voltage summing node and to the positive or negative power supply, for more or less current. Adjust the resistor's value for the proper range.

4a. READER'S EQUIPMENT: Additions to Terry Mikulic's VCF in EN#34.





These two circuits are intended for simplification of the VCF in EN#34. At left is the main control circuit, and above is the Q control circuit. More information on these techniques are found in sections 3, and 8a of this issue.