Voltage-controlled resistance switches over preset limits

by Chris Tocci
Halifax, Mass.

Using two field-effect transistors as switches, this voltage-controlled resistor network can order up any value of resistance between two preselected limits. It is unlike other circuits in that it does not employ the drain-to-source resistance of matched FETs, whose R_{ds} characteristics are usually proportional to a control voltage. As for circuit linearity, it will far exceed that of conventional networks using a single FET in various feedback configurations.[1]

In operation, oscillator A_1–A_2 generates a 0-to-10-volt triangle wave at 100 kilohertz, which is then compared with the control signal, V_c, at A_3. During the time that the control exceeds switching voltage V_T, FET Q_1 is turned on, and resistor R_1 is placed across resistance R_{out} (disregarding the R_{ds} of Q_1). At all other times, FET Q_2 is on and resistor R_2 is placed across R_{out}. Thus R_{out} is equal to an average value proportional to the time each resistor is placed across the output terminals, with the actual resistance given by $R_{out} = (R_1 - R_2)V_c/10 + R_2$, for $R_1 > R_2$. This relationship will hold provided any potential applied to the R_{out} port from an external device is less in magnitude than the supply voltages; that any signal processing at R_{out} be done at a frequency at least one decade below the 100-kHz switching frequency; and that the upper and lower resistance limits, R_1 and R_2, are much greater than the on-resistance of Q_1 and Q_2, respectively.

Potentiometer R_{11} adjusts the baseline of V_T to zero so that with $V_c = 0$, $R_{out}n = R_2$, where n is a constant. Further calibration can be carried out by trimming R_1 and R_2 to precise values.

This circuit is readily adapted to many applications, such as a one-quadrant multiplier. This is achieved by connecting a voltage-controlled current source into the R_{out} port to build a dc-shift amplitude modulator whose carrier frequency is the switching frequency. The audio information or data is taken from V_c, but with the signal offset by 5 volts. Thus the dynamic range of the circuit will be 10 V. □

References
1. Thomas L. Clarke, "FET pair and op amp linearize voltage-controlled resistor," *Electronics*, April 28, 1977, p. 111.

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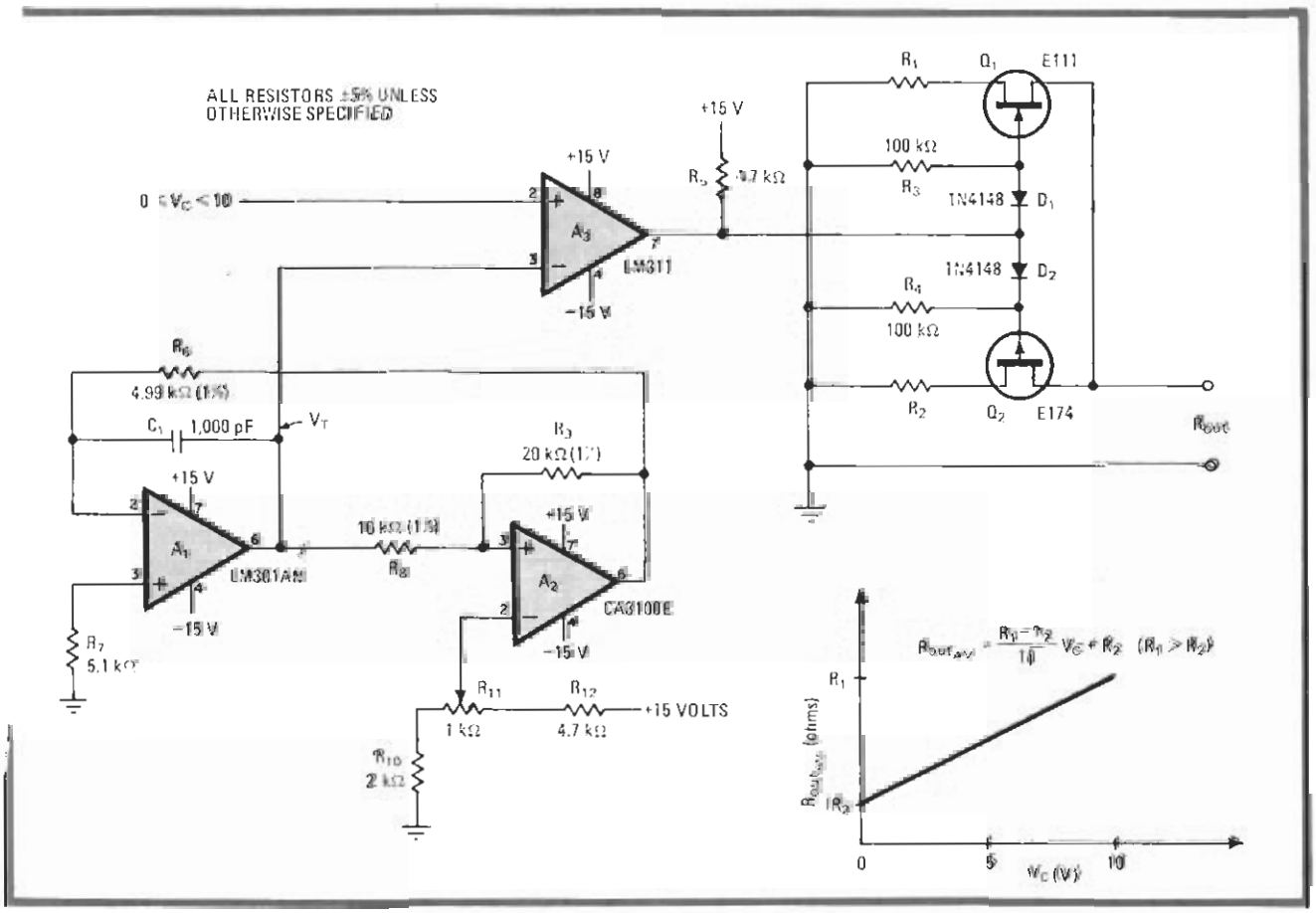

Ohmic linearization. FET switches in voltage-controlled resistor network place maximum-minimum resistors R_1 and R_2 across R_{out} so that the resistance is proportional to the average time each is across output port. Switching technique ensures piecewise-linear operation. This circuit lends itself to many applications, such as a-m modulator, by placing voltage-controlled current source across R_{out}.