

Today's Semiconductors

KARL SAVON
SEMICONDUCTOR EDITOR

THE DATA SHEET FOR THE RCA CA3160 BIMOS operational amplifier (File Number 976) describes a device similar to the earlier CA3130 but with internal compensation. This means that in a host of applications you don't have to figure out the value of capacitors or more complex compensation networks to stop your favorite circuit from oscillating.

CA3160 application

Suppose you have a microcomputer or some kind of counter hooked up as a music generator or in a measurement system and you would like to convert its 8-bit parallel output into an analog voltage. Digital-to-analog converters tend to get complicated and expensive, but the one shown in Fig. 1 is neither. This circuit has nine parallel inputs labelled MSB1 to LSB9, from the most significant to least significant bits. The converter uses an R-2R precision resistor network to weight the various binary inputs to produce the DC output voltage. Speed is a virtue of this type of converter since there are no closed-loop comparisons or sequencing operations to slow things down. It's simply a matter of reading the parallel inputs and the time it takes the switches to settle and the circuit capacitance to charge.

The CA3160 in Fig. 1 acts as a voltage follower that takes the output of the resistor network and buffers it to feed the system output. To maintain converter accuracy, it is vital not to load the resistor network. It doesn't take much to disturb the DC output voltage. The situation is similar to measuring with a DC

voltmeter. If the meter does not have a sufficiently high input impedance, it will load the finite impedance of the circuit and destroy the measurement accuracy.

The circuit uses five IC's; three CD4007's that serve as switches; the CA3160 voltage follower; and a CA3085 voltage regulator to supply a stable reference voltage. The system output cannot be any better than the reference voltage since all other errors are added to it.

The CD4007's are really COS/MOS amplifier stages. The input to each inverter amplifier is connected to each of the 9 digital inputs, and each corresponding output feeds one of the converter resistors. Starting at the most significant bit, notice that until you reach R7, the resistors keep doubling in value. Eight 806K's in parallel are about 100K; the next group on terminals 1 and 5 of IC3 combine to 100K, etc. A voltage on the most significant bit has the largest influence due to its lowest series resistance to the common output bus. As you move in the direction of the less significant bits, doubling the resistance value reduces their influence by one-half.

Assume for the moment that you are dealing with two input bits. These binary inputs are weighted in powers of two so that the most significant bit has a weight of 2 and the least significant bit has a weight of 1. If both bits are 0, the binary number is 0 and a 0-volt output is produced. If the least significant bit is a 1 and the most significant bit is a 0, the binary number is 1 and the output is one-fourth the reference voltage. A logic 1 on

the most significant of the two bits and a logic 0 on the other equals a 2, which produces an output of one-half the reference voltage. Both bits at a logic 1 level produce an output equal to three-fourths of the reference voltage. By weighting each input in binary fashion, the converter produces equal steps from 0 to three-fourths of the reference voltage. The same pattern holds for the 9-bit converter except the range of output steps is from 0 to 511.

The circuit should double the resistance value down to the end of the chain, but this would require a resistance range of 256 to 1, which creates some real practical problems. By inserting the 1556-ohm series resistance, the total converter network resistance range is limited to only 16:1, a much more manageable figure. The actual choice of resistor values is a compromise between speed and accuracy. The larger the resistance the slower the R-C time constants, and the smaller the resistors the larger the effect of the 250-ohm output resistance of the CD4007's.

Resistors R8 and R9 combine to form a 1.612 megohm resistance. The voltage swing at its upper end has a specific, voltage influence on network output. Resistor R5, the next one in the chain, must have exactly one-half this influence. If we separate R5 from the resistors to its left, we can draw the equivalent circuit shown in Fig. 2. If the circuit is opened at point x, the voltage at that point will change by

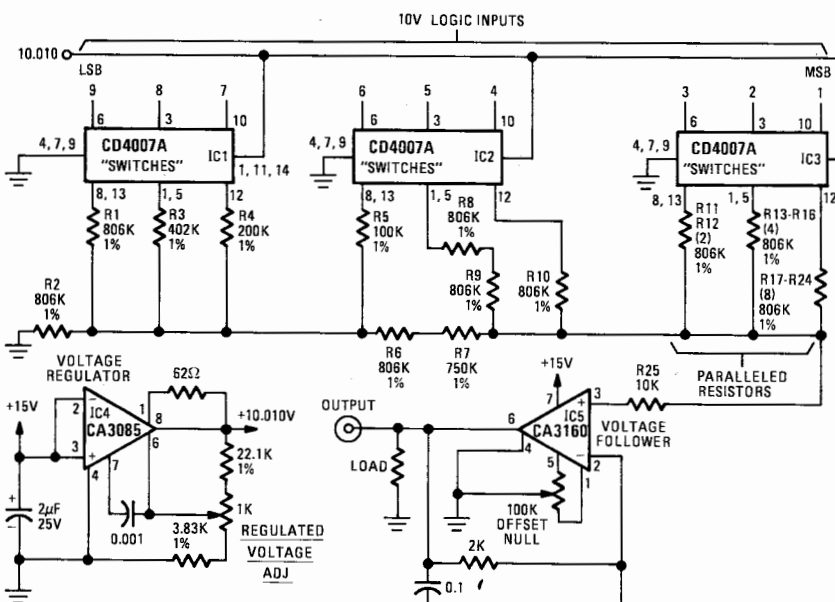


FIG. 1—DIGITAL-TO-ANALOG CONVERTER using the RCA CA3160 as a voltage follower.

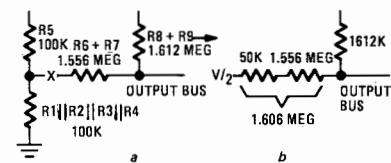


FIG. 2—EQUIVALENT CIRCUIT of the ladder network shown in Fig. 1 is shown in a. Simplifying the equivalent circuit yields the circuit shown in b.

one-half the supply when the top of R5 is switched. The resistance of this circuit is the parallel value of the two 100K resistances, or 50K. Added to the 1556 series resistance, the total resistance comes to 1606 ohms, similar to the R8 and R9 resistance.

The ladder network uses 1% metal film resistors. The most significant bits are assembled with parallel and series 806K resistors from the same lot. Paralleling resistors increases the probability of a good match between the components. The regulated voltage is adjusted higher than 10 volts to 10.01 volts to compensate for the loading of R2 to ground. R-E