Lab Notes

"For members only . . ." — the exclusive OR gate

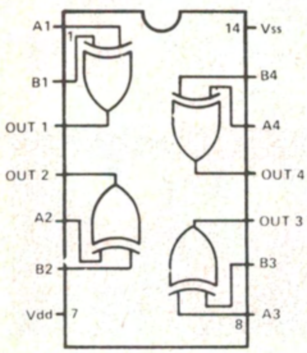
The 4070B quad EX-OR gate is one of the least known but most useful members of the commonly available family of CMOS quad two-input gate ICs. The device's gates can readily be used as programmable (inverting or non-inverting) pulse amplifiers, phase comparators, free-running or gated astables, or multi-bit magnitude checkers, etc. Pretty good for a cheap chip!

Ray Marston

THE OUTLINE and pin notations of the 4070B are shown in Figure 1, together with the truth table for each of the EX-OR gates in the package. The most important point to note here is that the output goes high only (EXclusively) if a logic 1 is applied to only one of the inputs (A OR B). The output takes a logic 0 state if identical inputs are applied to both inputs.

Figure 2 shows how individual gates can be used as programmable pulse amplifiers. With the connections shown in Figure 2a, the circuit functions as an inverting amplifier. In Figure 2b the amplifier acts in the non-inverting mode, while the Figure 2c circuit shows the connections for making a switch-programmable amplifier.

The EX-OR programmable amplifier can be used as the basis of a so-called scrambler system of the type used on security telephones, etc, by using the basic circuit shown in Figure 3. Here, in



A	B	OUT
0	0	0
1	0	1
0	1	1
1	1	0

1 OF 4 GATES

Figure 1. **Pin notations, outline and truth table of the 4070B quad two-input EX-OR gate.**

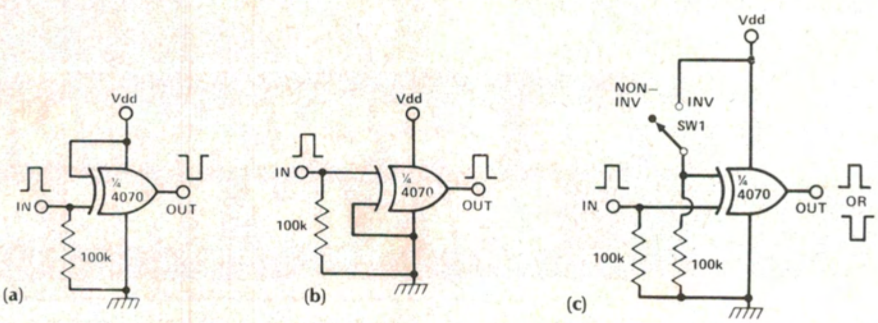


Figure 2. **The EX-OR gate can be used as an a) inverting, b) non-inverting, or c) switch programmable pulse amplifier.**

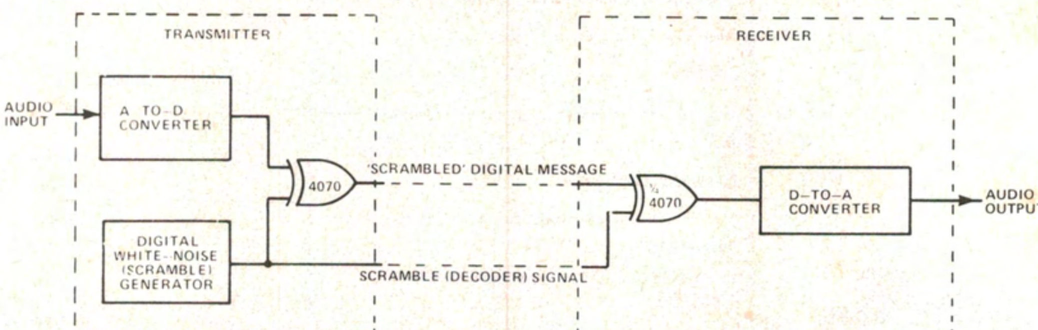


Figure 3. **Basic circuit of an audio (telephone, etc.) scrambler system.**

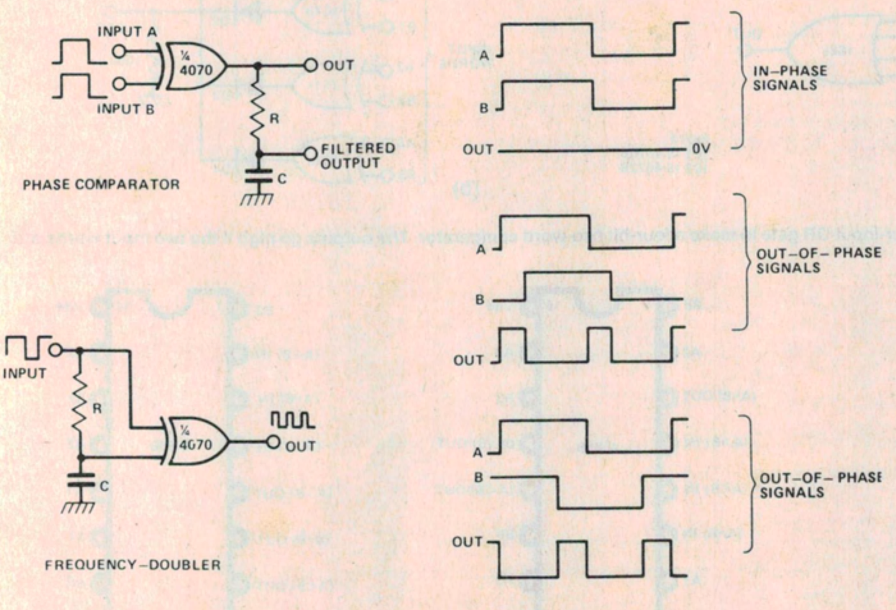


Figure 4. **An EX-OR gate can be used as both a phase comparator and a frequency doubler. Typical waveforms for the phase comparator circuit are shown on the right.**

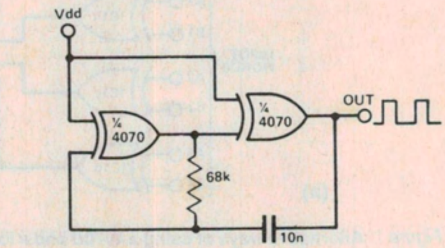


Figure 5. **A 1kHz EX-OR astable.**

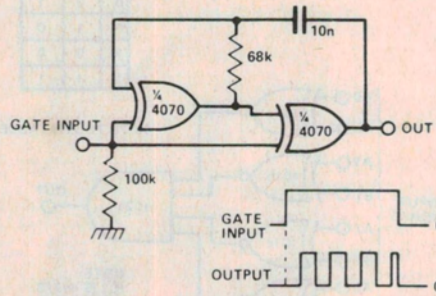


Figure 6. **A gated 1 kHz EX-OR astable.**

the transmitter, the audio signal is converted to digital form by an A-to-D converter and fed to one input of the EX-OR gate, while the other input is fed from a digital white noise or 'scramble' signal. The output of the EX-OR gate is thus inverted or non-inverted in a random manner and cannot readily be deciphered.

Both the scrambled message and the scramble signal are sent out (on separate lines) from the transmitter. At the receiver, the two signals are picked up and fed to the two inputs of a second EX-OR gate, where the digital analogue signal is restored (unscrambled) to its original form (the simple principle here is that if both gates are either inverted or non-inverted, the net effect will be an overall non-inversion of the signal). The restored digital signal is then converted back to analogue form by a D-to-A converter. Neat.

More circuits

Figure 4 shows ways of using an EX-OR gate as a digital phase comparator and as a frequency doubler. The two circuits use the same basic principle of operation, so let's look at the phase comparator first. The comparator is meant to be fed with digital (ideally, square wave) signals that are identical in form and frequency but which may differ in relative phase. A digital signal is available directly at the output of the gate, or a dc signal may be available from an R-C low-pass output filter.

From the circuit waveforms, you can see that if both input signals are precisely in phase the two inputs will always be identical and the output will be zero. If, on the other hand, the two signals are not in phase, the output switches high at those points in the waveform where the two inputs are in opposite logic states. This situation occurs twice in each input cycle, so the output signal is frequency doubled. The pulse width of the output signal and thus the mean dc output levels of both the gate and the low-pass filter are directly proportional to the magnitude of the phase difference between the two input signals. The level is low with a small phase difference, rises to a maximum at 180° difference and then reduces again as the phase difference is shifted from 180° towards 360°.

From the above, it is easy to see how the Figure 4 frequency doubling circuit works. The digital input signal is fed directly to the 'A' input terminal of the EX-OR gate but is fed to the 'B' terminal through the phase-shifting network formed by R-C; the resulting phase-shift implements the frequency doubler action.

Figure 5 shows how a pair of EX-OR gates can be used to make a 1 kHz astable multivibrator or square wave generator. The circuit operates as a standard CMOS astable, the two gates being made to function as pulse inverters by taking one of their two inputs high.

Figure 6 shows how to modify the above circuit so that it functions as a gated 1 kHz astable circuit. Useful features of this design are that it uses a logic 1 (high) gate signal and its output goes to the logic 0 (zero) state when the astable is gated off.

Magnitude comparators

We've already seen that the output of an EX-OR gate goes low if its two inputs are identical, or high if the inputs differ. The device can thus be used to compare a pair of digital bits, or a number of gates can be used to compare the magnitudes of a pair of multi-bit digital words. Figure 7 shows how a 4070B can be used to compare two four-bit words and give a high output if the two words are not identical. In Figure 7a, the ▶

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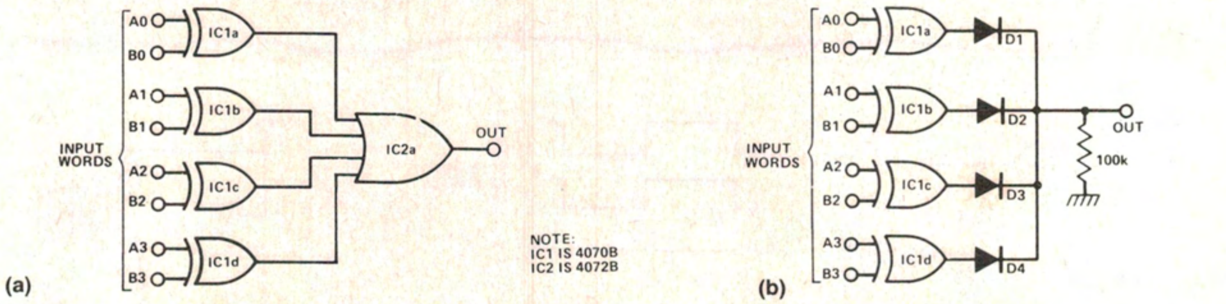

Figure 7. **Alternative ways of using a 4070B and a four-input OR gate to make a four-bit two-word comparator. The outputs go high if the two input words are not identical.**

A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	1

4077B TRUTH TABLE

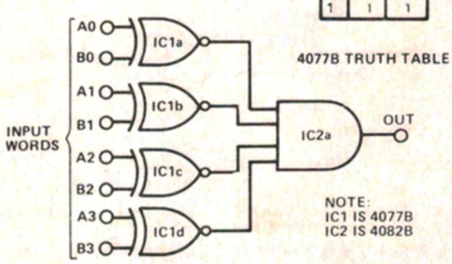

Figure 8. **Method of using 4077B EX-NOR gates to make a four-bit two-word comparator that gives a high output if the two input words are identical.**

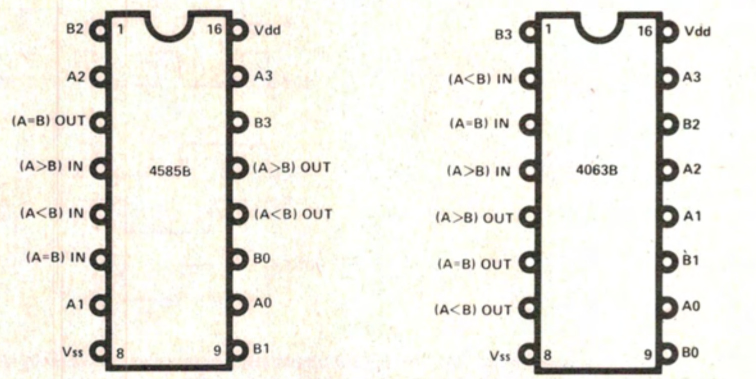

Figure 9. **The 4585B and the 4063B are four-bit magnitude comparator ICs.**

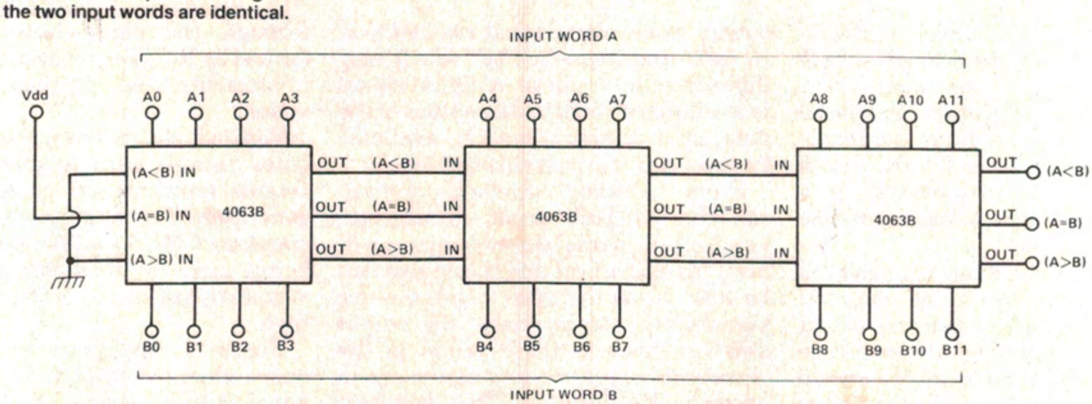

Figure 10. **Method of cascading three 4063Bs to make a 12-bit two-word comparator.**

outputs of the four EX-OR gates are ORed by one half of a 4072 dual four-input OR gate. In the Figure 7b circuit the outputs are ORed by a four-input diode gate.

An opposite action, in which the output goes high if the two words are identical, can be obtained by replacing the 4070B with a 4077B EX-NOR IC and ANDing the outputs by one half of 4082B, as shown in Figure 8. The 4077B has the same outline and pin notations as the 4070B.

The two magnitude comparator circuits described above are quite inexpensive and, clearly, are not particularly sophisticated. If a more sophisticated magnitude comparator performance is required, special chips such as the 4063B or 4585B four-bit magnitude comparators can be used. Figure 9 shows the outlines and pin notations of these two CMOS devices. Note that these chips have three outputs, one going high if the two words are identical, one if the 'A' word is greater than the 'B' word, and the remaining output going high if the 'A' word is less than the 'B' word. Obviously, only the one output can be high at any given time.

A useful feature of the 4063B and 4585B comparators is that they can readily be cascaded to compare words of any desired 'bit' length. Figure 10, for example, shows the basic connections for making a 12-bit comparator, using three cascaded ICs. When using these comparators, either singly or in cascade, note that the cascading inputs of the least significant comparator are connected as follows: (A<B) and (A>B) are biased low, and (A=B) is biased high. ●