Designing With Logic, Part 4

This month we're going to have a look at a bit of actual circuitry. In designing with logic, sometimes you just have to put your pencil away and get down to hot lead

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The simple sorts of logic arrays and single flip-flops that we've been looking at over the past few months rarely come up in real world logic design. Such things as binary adders, decade counters and so on are so commonly used that they're potted in single chips. Rather than having to wire together a binary adder, all you need do to have its functionality is to go spring about fifty cents for a single integrated circuit.

Logic design often assumes the aspect of assembling black boxes for this reason. After a while you'll stop being conscious of what the boxes are up to inside, only what their results are. In a sense, this is the proper mindset for designing with logic. The truth table of a logic array... whether it has been wired together with individual gates or potted in a chip... is the only thing that really matters. Transistors are for radio designers.

This month we're going to look at a very simple bit of logic design, but one that's both interesting and a spingboard to larger efforts. With two chips and an LED display, you can make your soldering iron count to ten.

Sixteen Fingers

The object of this exercise is to create a circuit which will count input pulses. The current count will be shown on a seven segment LED display. Because this is a simple counter, we'll only have one digit on hand. When the count exceeds nine it will wrap back to zero.

There are two basic problems to be overcome in this design. The first one is to find a way to count to ten. The second is to find a way to make the binary representation of numbers produced by a counter into something a seven segment LED display can make some sense of.

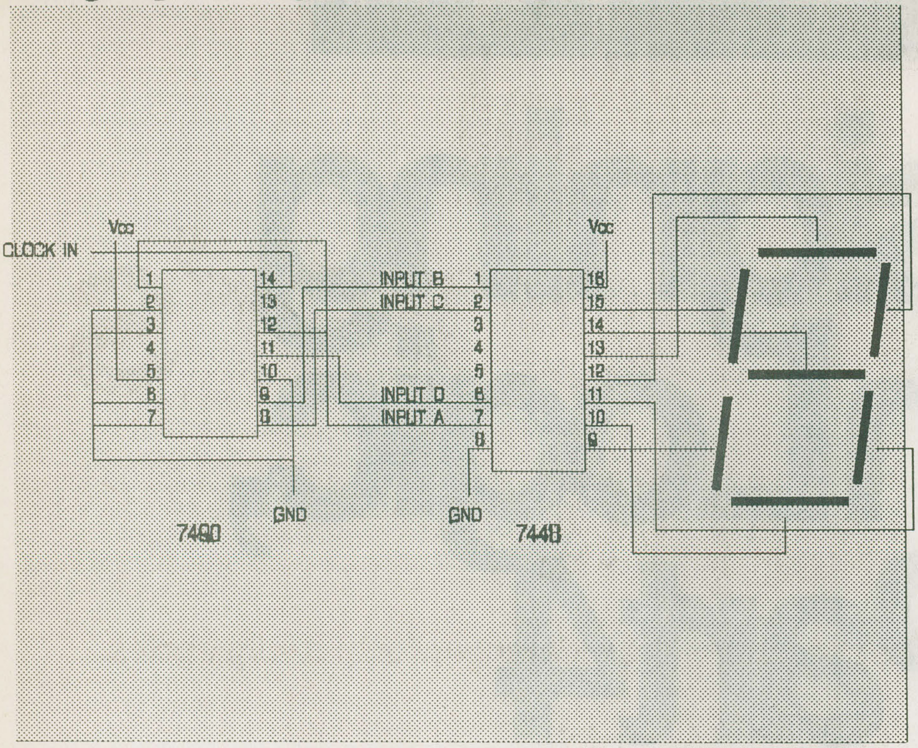
Counting with logic, as we saw last month, isn't particularly difficult.

A single flip flop is essentially a frequency divider or, if you like, a box that counts to two. The output of the flip flop will go high upon every second input pulse. An array of two flip flops with the input of the second connected to the output of the first will count to four. Three will count to eight and four to sixteen. We only want to count to ten. Ten, regrettably, is not an even power of two.

In order to count to ten, as we discussed last month, one must watch the outputs of the four flip flops and reset the counter when the number ten appears. As such, the counter will be forced to wrap at ten rather than at sixteen.

The 7490 chip consists of four flip flops and all the logic necessary to make it reset at ten. This single package replaces four discrete chips. All you have to do is to send some pulses into its A_{IN} input and a four bit binary number ranging from zero through ten will appear at its output.

It's worth noting that the internal structure of the 7490 is a bit more complex than it may appear at first. It actually consists of a single flip flop for the first stage counter followed by three more flip flops and the gates to make them reset. As such, while we've made it behave like a decade counter by simply wiring the output of the first flip flop to the input of the remaining three, it can also be used in other ways.



The first flip flop can be a divide by two counter and the other three a divide by five counter if you have need of these facilities.

The R_{01}, R_{02}, R_{91} and R_{92} inputs of the 7490 are grounded in this circuit. In some applications it's useful to be able to explicitly reset a counter, or bank of counters, to a known state before you start counting. This is handled by the R inputs. The 7490 allows for a variety of reset options. You can "jam" either a zero or a nine value into the counter prior to counting.

In this simple application it doesn't really matter where the counter starts, so we won't worry about the R inputs.

The second half of the circuit is the logic to turn the binary coded output of the counter into the on and off states to drive a seven segment LED display. Now, while the complexity of such a task might seem a bit daunting, its nature will be familiar to you. The black box in question has four inputs, corresponding to the four outputs of the counter, and seven outputs, one for each segment of the LED display. It's a finite state logic array, and can be represented by a truth table, if rather a large one.

truth table

DECIMAL OR FUNCTION	INPUTS						BI/RBO†	OUTPUTS							NOTE
	LT	RBI	D	C	B	A		a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	H	H	H	H	H	H	L	1
1	H	X	L	L	L	H	H	L	H	H	L	L	L	L	1
2	H	X	L	L	H	L	H	H	H	L	H	H	L	H	
3	H	X	L	L	H	H	H	H	H	H	H	L	L	H	
4	H	X	L	H	L	L	H	L	H	H	L	L	H	H	
5	H	X	L	H	L	H	H	H	L	H	H	L	H	H	
6	H	X	L	H	H	L	H	L	L	H	H	H	H	H	
7	H	X	L	H	H	H	H	H	H	H	L	L	L	L	
8	H	X	H	L	L	L	H	H	H	H	H	H	H	H	
9	H	X	H	L	L	H	H	H	H	H	L	L	H	H	
10	H	X	H	L	H	L	H	L	L	L	H	H	L	H	
11	H	X	H	L	H	H	H	L	L	H	H	L	L	H	
12	H	X	H	H	L	L	H	L	H	L	L	L	H	H	
13	H	X	H	H	L	H	H	H	L	L	H	L	H	H	
14	H	X	H	H	H	L	H	L	L	L	H	H	H	H	
15	H	X	H	H	H	H	H	L	L	L	L	L	L	L	
BI	X	X	X	X	X	X	L	L	L	L	L	L	L	L	2
RBI	H	L	L	L	L	L	L	L	L	L	L	L	L	L	3
LT	L	X	X	X	X	X	H	H	H	H	H	H	H	H	4

If you wanted to, you could design a logic array to generate this truth table. In practice, it would be somewhat enormous.

The 7448 chip consists of all the logic to drive a seven segment display. It's dead easy to work with. In addition, it has a few other useful features, such as the ability to blank the display during periods when the data being sent to it might not be valid. This is useful, for example, in applications wherein the counter driving the display decoder might spend part of its time counting and, as such, in flux. Blanking the display for a fraction of a second while its counter is updating doesn't make it go dark, but just a little dimmer. Persistence of vision allows us to see it as continuously illuminated.

Bigger Numbers

This little counter doesn't do very much, but you can make it into bigger things. For example, if you build a second one and gang them together, you can count from zero to ninety-nine. You can gang up as many decades of counters as you like.

In practice, wiring up eight lines... seven segments and ground... to every digit of a display is impractical. It's also unnecessary. Commercial devices which use seven segment readouts drive them through a technique called "multiplexing". In this case, there would be only one 7448, with its seven outputs connected to all the segments of the display. In practical terms, it would usually be necessary to use transistors to buffer the outputs of the 7448. Each of the common ground lines of the displays would be driven by a multiplex generator. This is simply a chip which accepts a binary input and turns on one of its output lines at a time.

In order to drive this display, then, a multiple decade counter would have to output two binary numbers... one to decide on which digit to display and one to select which of the LED displays it's to appear on. By scanning through all the LED displays quickly enough, someone looking at the readout would see all of them illuminated, even though only one is on at a time.

We'll look at counters and displays in greater detail next month, and we'll be back to details of handling a multiplexed display later in this series. ■