Lab 12: Counters, Decoders, Drivers, and LED Displays

Purpose: To introduce the student to several MSI chips (medium-scale integrated circuits) that illustrate the ease with which digital readouts in the form of numeric displays can be configured.

Concepts: This experiment covers binary-coded decimal (BCD) coding, the 7490 counter chip, the 7447 BCD-to-seven segment decoder/driver, and seven segment LED display modules.

Introduction: One advantage of digital circuitry is the low cost and unambiguious nature of its output devices. Whereas analog meters cost $50 or more and pose visibility, parallax, and durability problems, digital output devices such as numeric displays can be inexpensive, unambiguous, and very durable. Modern technology provides a choice of readout devices, the principal ones being liquid crystal displays (such as the ones frequently found on digital watches), gas discharge numerals, and seven-segment numerals based on light-emitting diodes (LEDs). For this experiment we choose the seven-segment LED display, which is a natural choice when one needs only a few digits of modest size and when power consumption is not a consideration. One of the convenient features of LED displays is the simple requirement that only one +5V power is needed (other types of displays require substantially higher voltages). In this experiment the seven-segment readout will display the accumulated count of a medium-scale integrated circuit (MSI) counter chip that receives pulses from the Digi-Designer's clock.

The student is expected to operate more independently in this experiment. For instance the student should consult the attached specification sheets to determine details of the wiring and operation of the chips. Figure 1 shows the general layout of the counter/display circuit to be constructed. A low frequency but continuous pulse train (approximately 1 Hz) from the Digi-Designer's clock constitutes the input to be counted by the 7490 decade counter chip. As the 7490's spec sheet states, this chip consists of four master-slave flip-flops wired internally as a counter. The chip also has several reset lines for count inhibiting and clearing. Several modes of operation are possible, but in this experiment you are to use the 7490 in its decade counting mode.

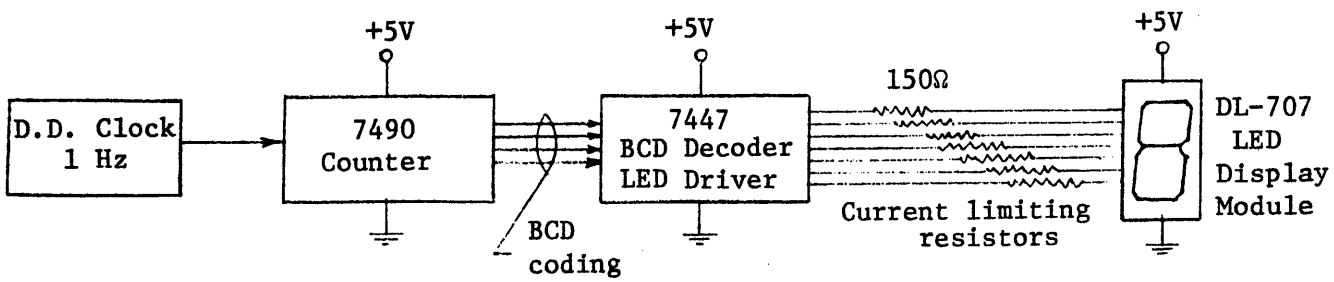


Fig. 1. Block diagram for counter/decoder/display circuit.

In this case, the chip counts from 0 to 9, and provides the instantaneous count in a binary-coded decimal (BCD) format on output bits A, B, C, and D available on pins 12, 9, 8 and 11 respectively. For operation as a counter, the 7490 requires +5V on pin 5, a ground connection on pin 10, and the input pulse train on pin 14. Output pin 12 must be connected to pin 1 for decade counting, and pins 3 and 6 must be grounded to permit counting. The student should consult the 7490 spec sheet for details regarding wiring and BCD coding.

The TTL outputs on pins 12, 9, 8 and 11 of the 7490 should be connected to the Digi-Designer's lamp monitors (so that you can observe the 4-bit BCD output of the 7490) as well as the input pins 7, 1, 2, and 6 respectively of the 7447 decoder/driver. The 7447 decodes the BCD information and generates Hi's or Lo's as necessary to drive the proper segment(s) of the seven-segment readout. The 7447's seven output lines (that connect to the display module) are available on pins 9 through 15. Each of these outputs is an "open-collector" of an NPN transistor that needs an external load ultimately tied to a +5V power supply. In our experiment, the seven LED elements constitute the seven necessary loads, i.e. these LED elements complete the transistors' output circuits to the +5V supply. Of course, the 7447 needs power and grounding apart from the disposition of the output circuits; refer to the 7447 specification sheet for details.

Unfortunately, the LED elements in the Litronix DL-707 seven-segment display would, if left to themselves, draw too much current and self-destruct. To prevent this from happening, we wire a 150 ohm current-limiting resistor in series with each LED element. The seven necessary resistors are pre-mounted on an IC-like socket that plugs into the Digi-Designer as if it were a chip. So, in practice, each of the seven output lines from the 7447 must be routed to a resistor before connection to the proper cathode pin (cathode pins A through G) on the DL-707 display. The seven LED anodes on the DL-707 are partially connected internally, but the module requires external jumpers between pins 3, 9, and 14 for anode interconnection. Then one of these jumpered pins should be connected to the +5V supply to complete all the anode circuits. Each LED element can be viewed as a diode with separate anode and cathode; to light any LED element on the DL-707, roughly 10 mA of positive current must pass from anode to cathode. This current is controlled by the output transistors in the 7447 decoder/driver. When the collector of one of these transistors goes Lo, the required current passes from the +5V supply through the LED element and the external resistor and into the collector of the driving transistor. On the other hand, when this transistor goes Hi, insufficient voltage exists between the +5V supply and the collector to turn on the LED; hence it remains off. *Be careful not to short circuit the 150 ohm resistors;* otherwise you might burn out the DL-707 as well as the 7447!

After wiring up the circuit, turn on the Digi-Designer's clock and marvel at your single-digit recycling counter! The cost of the entire circuit you have constructed is about $5.

DECADE COUNTER

N7490

DIGITAL 54/74 TTL SERIES

DESCRIPTION

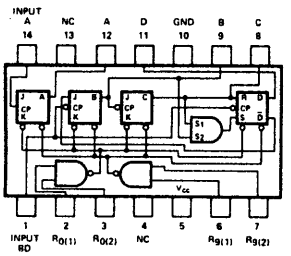
The 7490 is a high-speed, monolithic decade counter consisting of four dual-rank, master-slave flip-flops internally interconnected to provide a divide-by-two counter and a divide-by-five counter. Gated direct reset lines are provided to inhibit count inputs and return all outputs to a logical "0" or to a binary coded decimal (BCD) count of 9. As the output from flip-flop A is not internally connected to the succeeding stages, the count may be separated in three independent count modes:

1. When used as a binary coded decimal decade counter, the BD input must be externally connected to the A output. The A input receives the incoming count, and a count sequence is obtained in accordance with the BCD count sequence truth table shown above. In addition to a conventional "0" reset, inputs are provided to reset a BCD 9 count for nine's complement decimal applications.
2. If a symmetrical divide-by-ten count is desired for frequency synthesizers or other applications requiring division of a binary count by a power of ten, the D output must be externally connected to the A input. The input count is then applied at the BD input and a divide-by-ten square wave is obtained at output A.
3. For operation as a divide-by-two counter and divide-by-five counter, no external interconnections are required. Flip-flop A is used as a binary element for the divide-by-two function. The BD input is used to obtain binary divide-by-five operation at the B, C, and D outputs. In this mode, the two counters operate independently; however, all four flip-flops are reset simultaneously.

The 7490 is completely compatible with Series 74 logic familes. Average power dissipation is 160mW.

PIN CONFIGURATION

A,F PACKAGE



LOGIC TRUTH TABLES

BCD COUNT SEQUENCE (See Note 1)

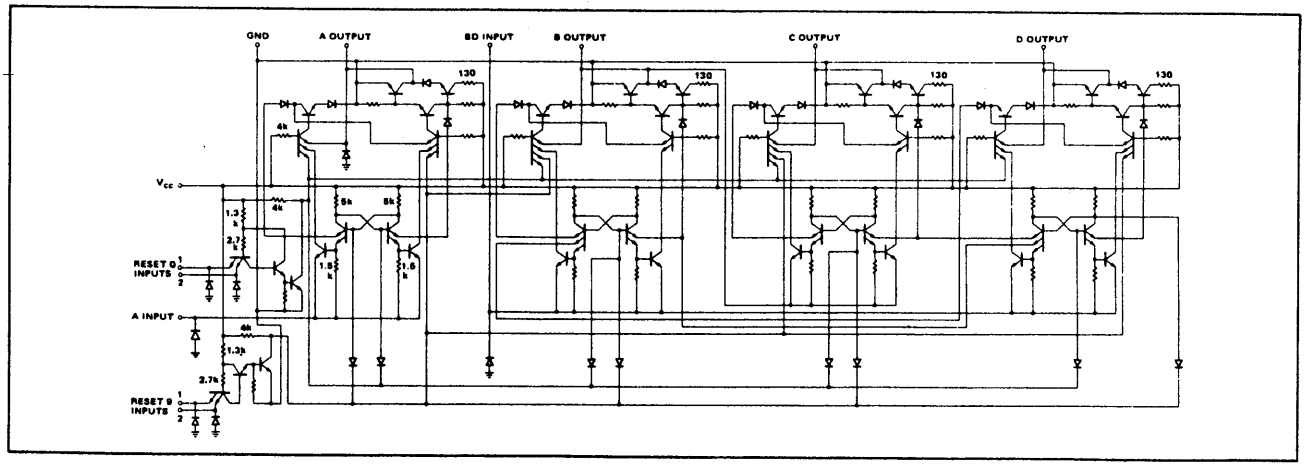
COUNT	OUTPUT D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

RESET/COUNT (See Note 2)

RESET INPUTS $R_{0(2)}$	$R_{0(2)}$	$R_{9(1)}$	$R_{9(2)}$	OUTPUT D C B A
1	1	0	X	0 0 0 0
1	1	X	0	0 0 0 0
X	X	1	1	1 0 0 1
X	0	X	0	COUNT
0	X	0	X	COUNT
0	X	X	0	COUNT
X	0	0	X	COUNT

NOTES:
1. Output A connected to input BD for BCD count.
2. X indicates that either a logical 1 of a logical 0 may be present.
3. Fanout from output A to input BD and to 10 additional Series 54/74 loads is permitted

SCHEMATIC DIAGRAM



BCD-TO-SEVEN SEGMENT DECODER/DRIVER

N7447

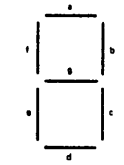
DIGITAL 54/74 TTL SERIES

DESCRIPTION

The 7447 BCD-to-Seven Segment Decoder/Driver are TTL monolithic devices consisting of the necessary logic to decode a BCD code to seven segment readout plus selected signs.

Incorporated in this device is a blanking circuit allowing leading and trailing zero suppression. Also included is a lamp test control to turn on all segments.

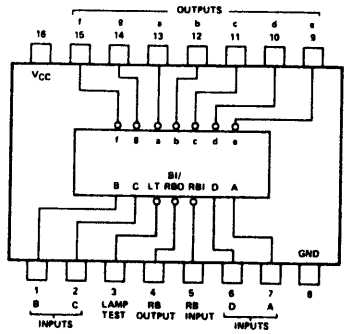
The 7446 and 7447 provide bare collector output transistors for directly driving lamps. The output transistor breakdown of the 7446 is 30 volts and the 7447 is 15 volts.



SEGMENT IDENTIFICATION

PIN CONFIGURATION

B PACKAGE

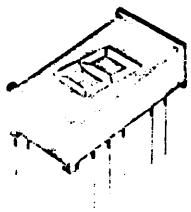


TRUTH TABLE

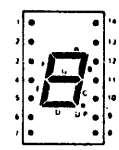
	INPUTS							OUTPUTS							
DECIMAL OR FUNCTION	LT	RBI	D	C	B	A	BI/RBO	a	b	c	d	e	f	g	NOTE
0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1
1	1	x	0	0	0	1	1	1	0	0	1	1	1	1	1
2	1	x	0	0	1	0	1	0	0	1	0	0	1	0	
3	1	x	0	0	1	1	1	0	0	0	0	1	1	0	
4	1	x	0	1	0	0	1	1	0	0	1	1	0	0	
5	1	x	0	1	0	1	1	0	1	0	0	1	0	0	
6	1	x	0	1	1	0	1	1	1	0	0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

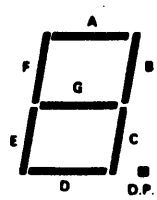
NOTES:

1. BI/BRO is wire-OR logic serving as blanking input (BI) and/or ripple-blanking output (RBO). The blanking input must be open or held at a logical 1 when output functions 0 through 15 are desired and ripple-blanking input (RBI) must be open or at a logical 1 during the decimal 0 input. X = input may be high or low.
2. When a logical 0 is applied to the blanking input (forced condition) all segment outputs go to a logical 1 regardless of the state of any other input condition.
3. When ripple-blanking input (RBI) is at a logical 0 and A = B = C = D = logical 0, all segment outputs go to a logical 1 and the ripple-blanking output goes to a logical 0 (response condition).
4. When blanking input/ripple-blanking output is open or held at a logical 1, and a logical 0 is applied to lamp-test input, all segment outputs go to a logical 0.

SINGLE DIGIT NUMERIC DISPLAYS	Part Number	Alternate Source Part Number	Character Height	Polarity	Description	Light output (Typical)	Forward Voltage (Typical)
	DL-707	MAN-7	0.30"	Common Anode	Low cost, 7 segment, solid bar, D. P. left, 14-pin DIP	0.7 MCD @ 10 mA	1.7V I_F = 20 mA
	DL-707R				Low cost, 7 segment, solid bar, D. P. right 14-pin DIP		
	DL701				±1 polarity/overflow version of DL-707		
	DL-702			Common Cathode	Common Cathode Version of DL-707 left decimal		
	DL-704	MAN-4			Common Cathode Version of DL-707 right decimal		

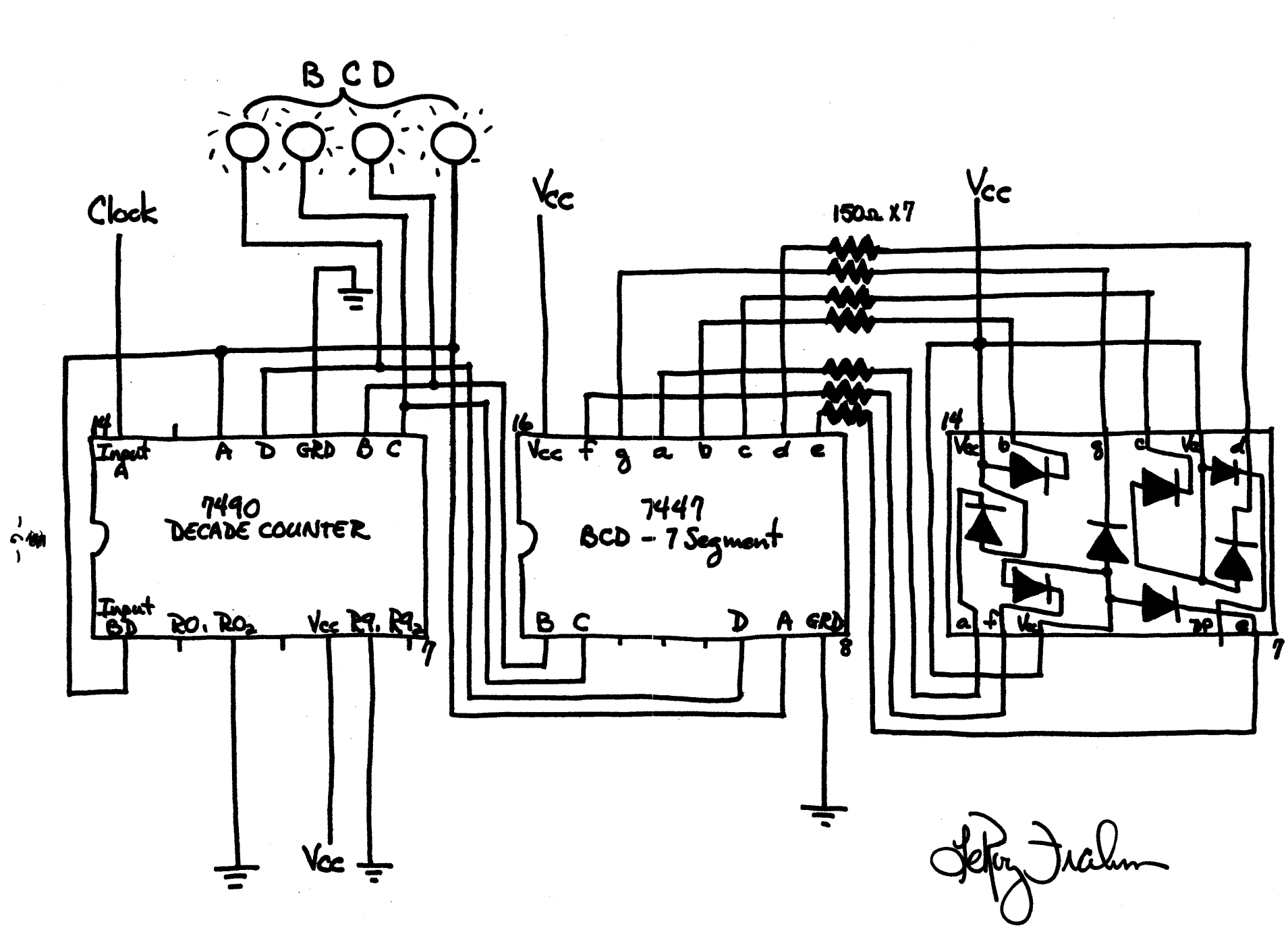
PIN FUNCTION





PIN	DL-707 (Note 1)
1	Cathode A
2	Cathode F
3	Common Anode
4	NC
5	NC
6	Decimal Point Cathode
7	Cathode E
8	Cathode D
9	Common Anode
10	Cathode C
11	Cathode G
12	NC
13	Cathode B
14	Common Anode

Notes: 1. Jumper Pins 3, 9, and 14 on Circuit Board for Common Anode.


B C D
Clock
Vcc
150Ω x7
Vcc
14
Input A
A D GRD B C
7490
DECADE COUNTER
Input B
R0, R0₂ Vcc R9, R9₂
7
16
Vcc f g a b c d e
7447
BCD - 7 Segment
B C D A GRD
8
14
Vcc b g c Vcc d
a f Vcc
7
Vcc