ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

Testing of Digital Circuits at RIT

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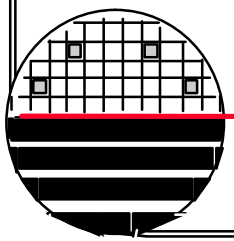
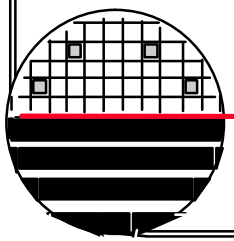


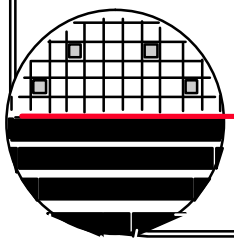
OUTLINE

Problem Statement
Digital Circuits
Tester Hardware
Tester Software
2 Input 1 Output
..
6 input 6 Output
Summary
References



PROBLEM STATEMENT

We design and build a variety of digital circuits which can not be tested using the HP-4145 Semiconductor Parameter Analyzer. These digital circuits often have a large number of inputs and outputs. For example a full adder has 3 inputs and 2 outputs. A 2-bit multiplexer has 6 inputs and 1 output. The chip technology could be PMOS, NMOS, CMOS, TTL or Analog each requiring different supply voltages. It is desirable to have a test system that can be easily understood with a simple graphical interface that can exercise these digital circuits. Test results in a format similar to the simulation results would be useful.

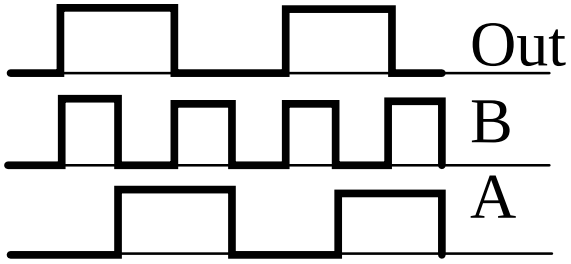


LIST OF DIGITAL CIRCUITS ON RIT TESTCHIPS

Inverters
2 Input NOR
XOR
2 Input NAND
RS Flip Flop
Multiplexer
Demultiplexer
Encoder
Decoder
Adder
PLA

For these types of devices a truth table type test at low frequencies would be sufficient.

A	B	Out
0	0	0
0	1	1
1	0	1
1	1	0



Similar to QUICKSIM output

NOR GATE AND NOR FLIP FLOP

PMOS 2 INPUT NOR

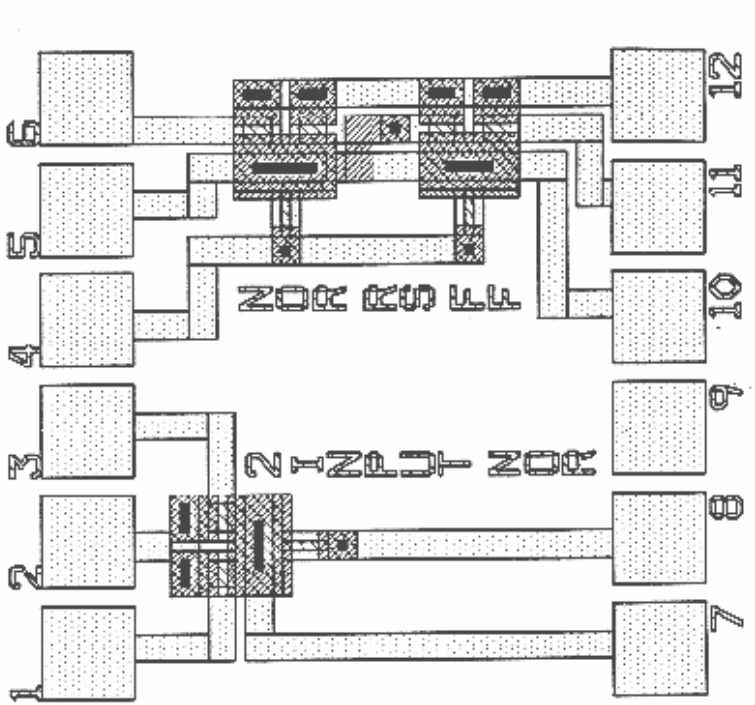
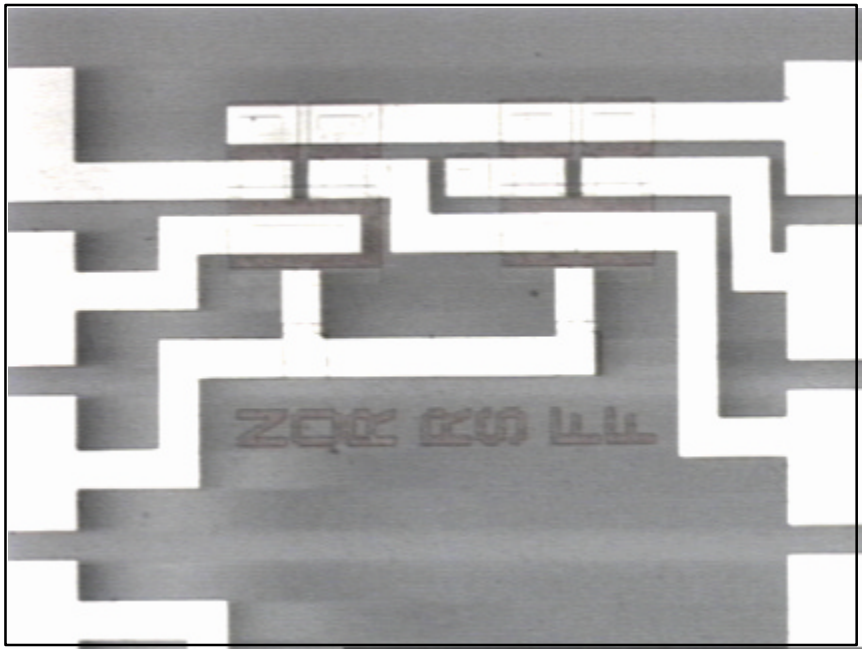
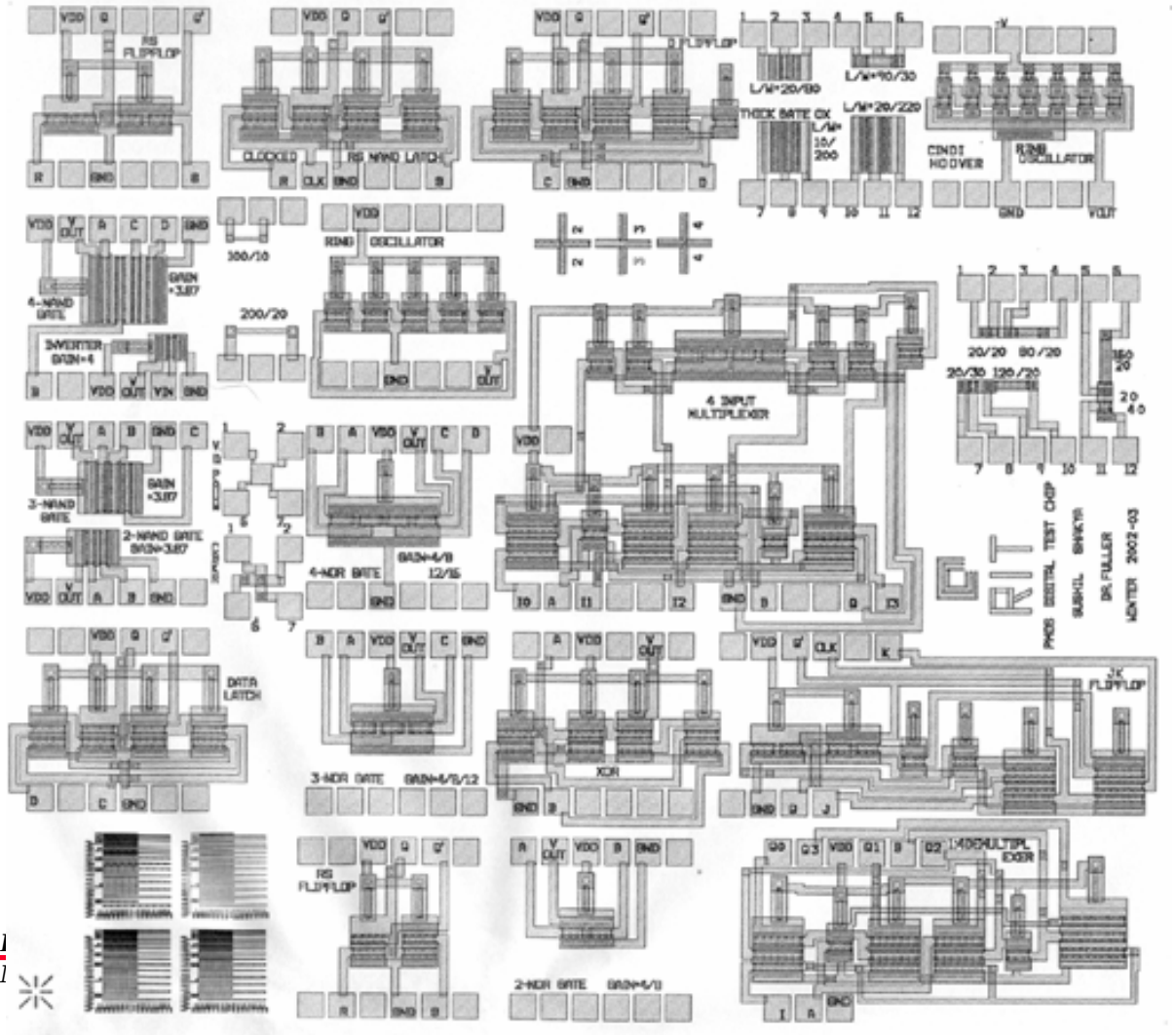


Figure 7 DIGITAL DEVICES

PMOS NOR RS Flip Flop

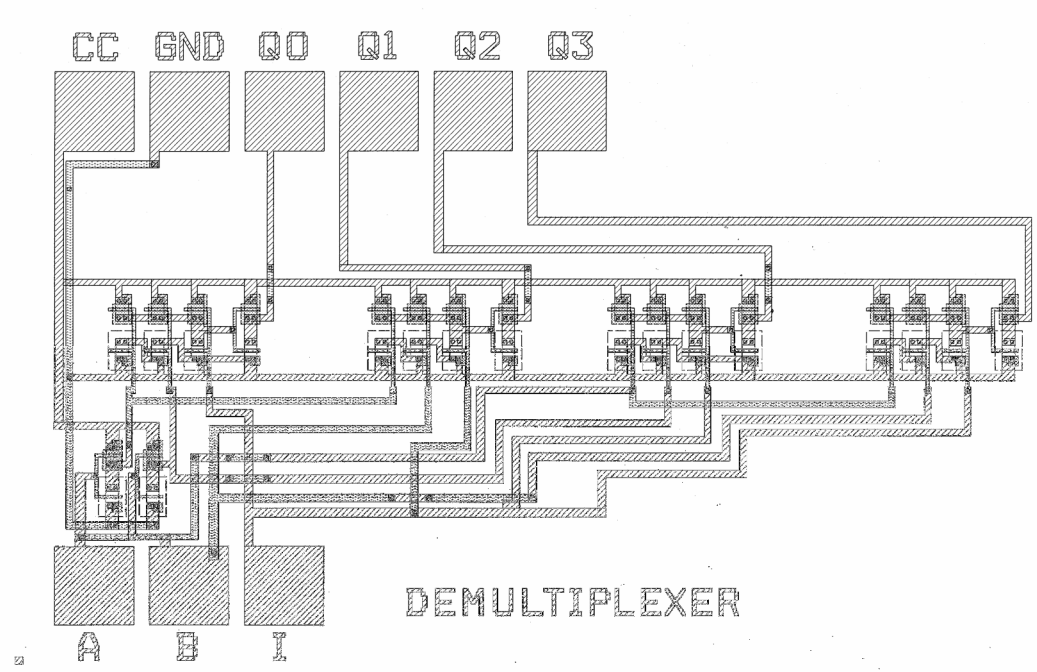


PMOS TEST CHIP

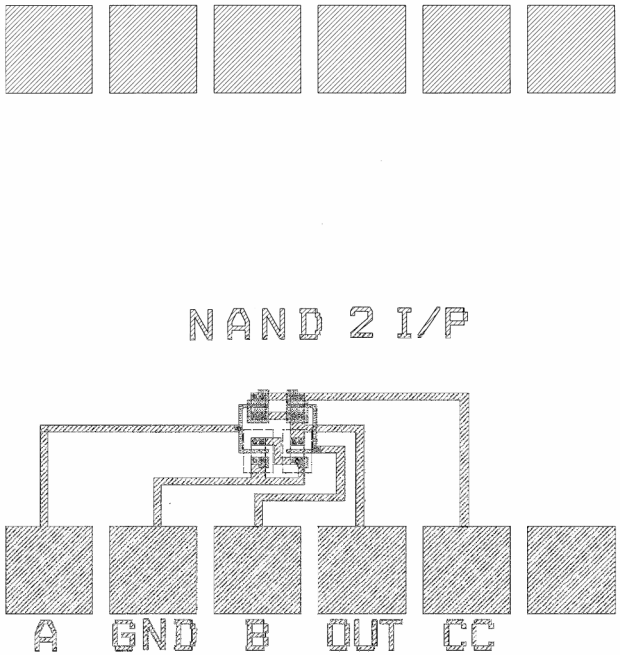


OTHER DIGITAL CIRCUITS

CMOS Demultiplexer



CMOS 2 INPUT NAND

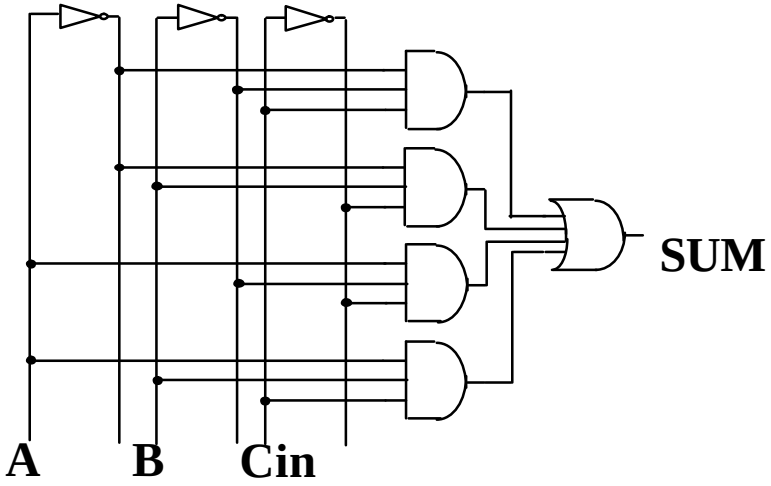


FULL ADDER CIRCUIT REALIZATION OF SUM

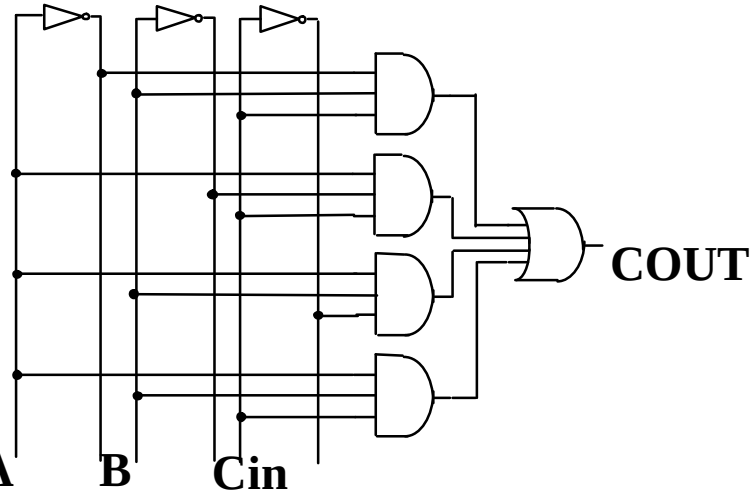
Sum = A'B'Cin + A'BCin' +AB'Cin' + ABCin

TRUTH TABLE FOR ADDITION RULES

A	B	CIN	SUM	COUT
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

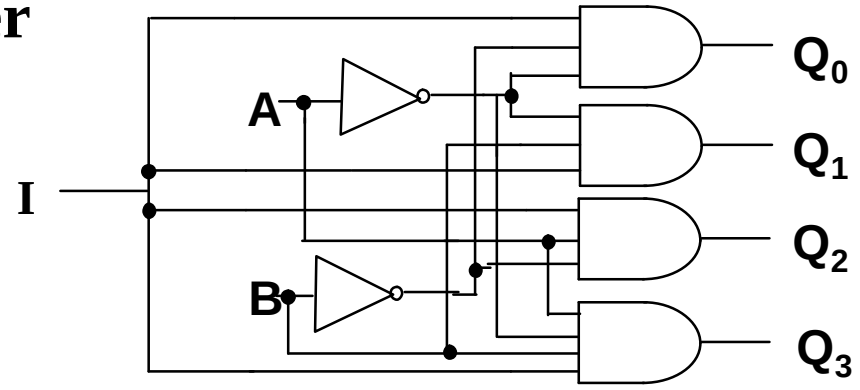


Carry Out = A'BCin + AB'Cin + ABCin' + ABCin



1:4 DEMULTIPLEXER

Demultiplexer



Q_0 = A'B'I so that when I=0 Q_0 =0
or when I=1 Q_0 = 1
similarly for Q_1, Q_2 and Q_3 Q_1 = A'BI

INPUTS		OUTPUTS			
A	B	Q_0	Q_1	Q_2	Q_3
0	0	I	0	0	0
0	1	0	I	0	0
1	0	0	0	I	0
1	1	0	0	0	I

FOUR INPUT MULTIPLEXER

select		output
A	B	Q
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

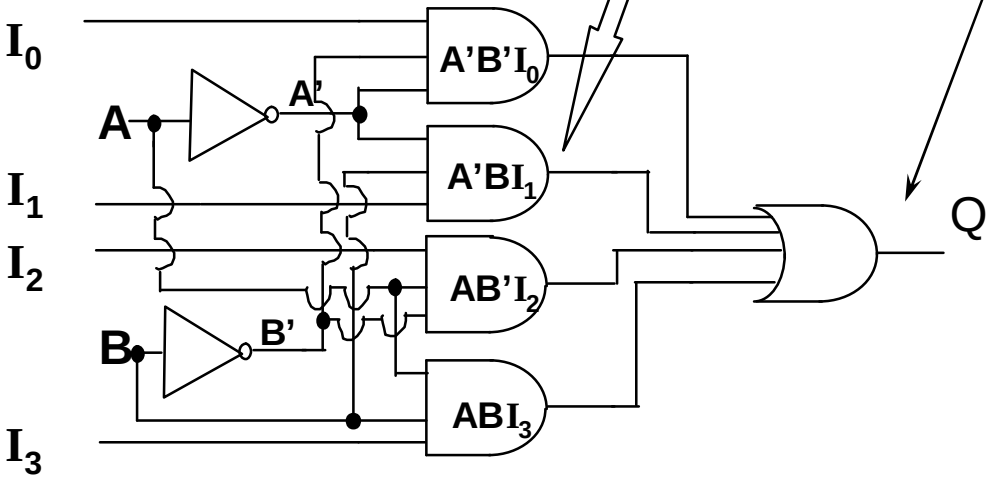
0 1 0 1 0 1 0 1

$$Q = A'B'I_0 + A'BI_1 + AB'I_2 + ABI_3$$

3 input AND

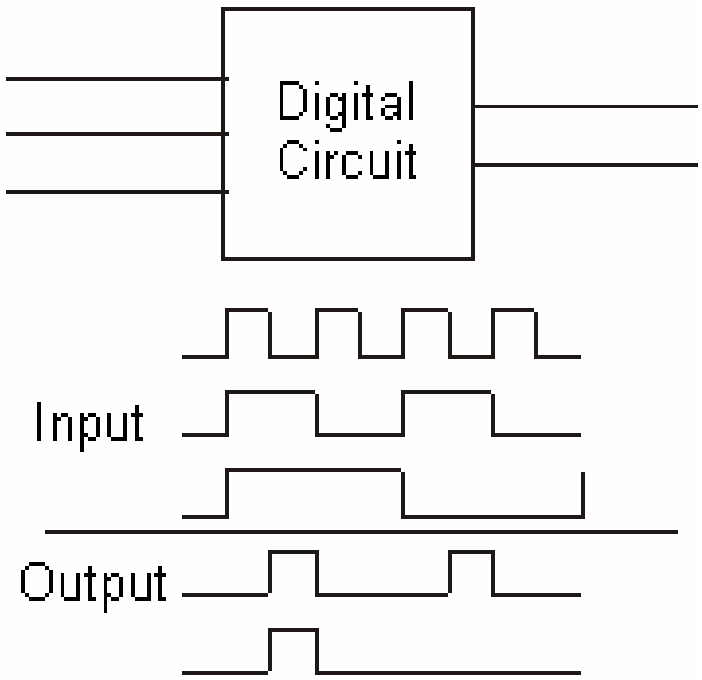
3 input AND

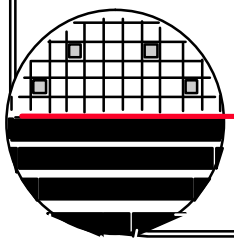
4 input OR



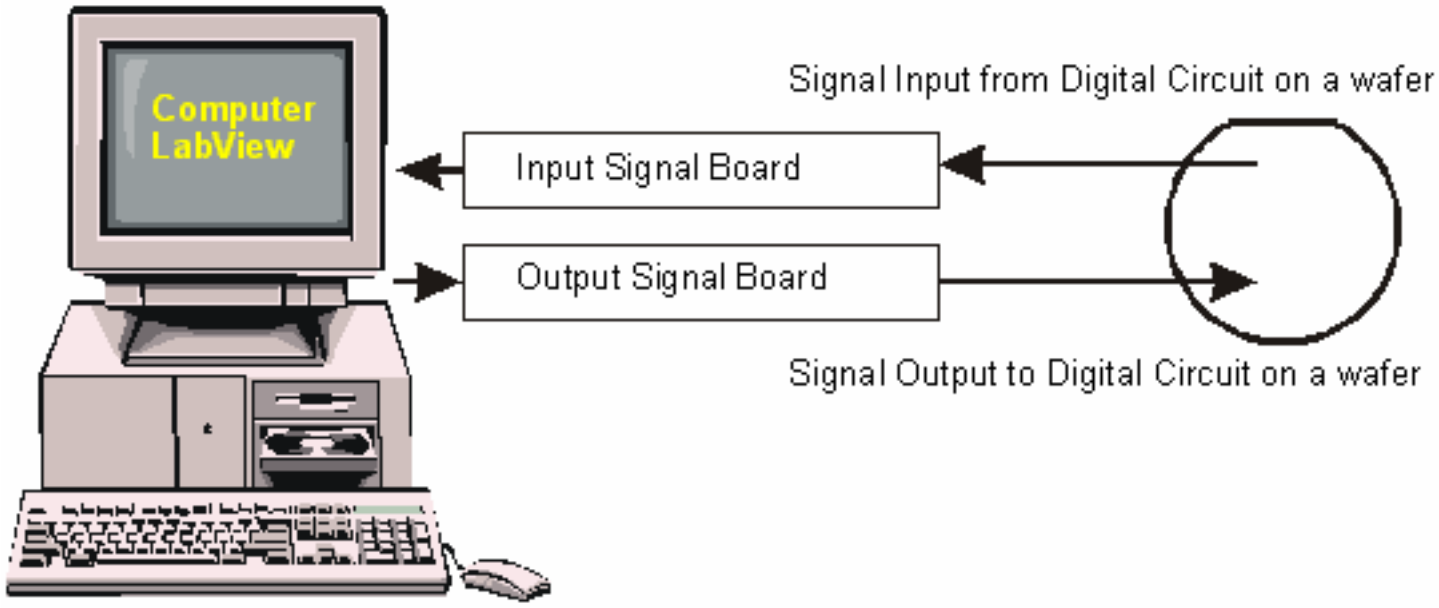
Four Input Multiplexer

DIGITAL CIRCUIT TESTING





LAB VIEW SOFTWARE



HARDWARE FOR OUTPUT

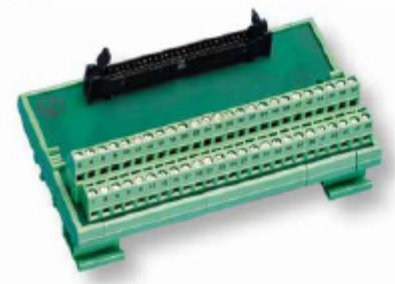
AT-AO-6

- Available for ISA computers
- 6 analog outputs; 12-bit resolution, 300 kS/s maximum update rate
- 8 digital I/O lines (5 V/TTL)
- 4-20 mA current sinks
- NI-DAQ driver with DAQ channel wizard for reduced configuration

NB1

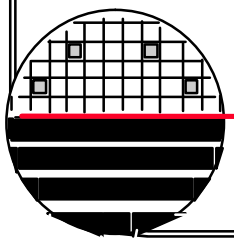
- 50-pin ribbon cable for any board with a 50 pin connector
- Connects to 50pin connector accessories
- 1 m and 2 m length options
- Download PDFs for compatibility charts, more detailed descriptions, and ordering information

CB50



- Low-cost accessory with 50 screw terminals for easily connecting field I/O signals to your DAQ board
- One 50-pin header for directly connecting to 50-pin cables
- Mounts on a standard DIN rail or flush on a wall or panel
- Dimensions: 13.5 by 7.3 cm (5.3 by 2.9 in.)
- Download PDFs for compatibility charts, more detailed descriptions, and ordering information

6 Analog Outputs
Ribbon Cable
Terminal Board



HARDWARE FOR INPUT

AT-MIO-16E-10

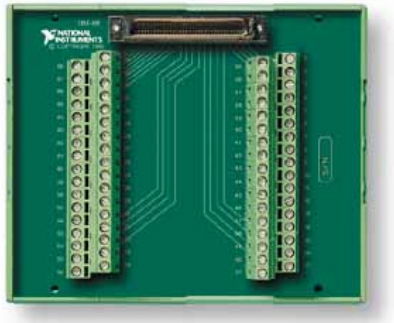
- Available for ISA computers
- Up to 16 analog inputs; 12-bit resolution; 100 kS/s sampling rate
- Two 12-bit analog outputs; 8 digital I/O lines; two 24-bit counters
- Calibration certificate included for NIST traceability
- NI-DAQ driver with DAQ channel wizard for reduced configuration

16 Analog Inputs
Ribbon Cable
Terminal Board

R6868

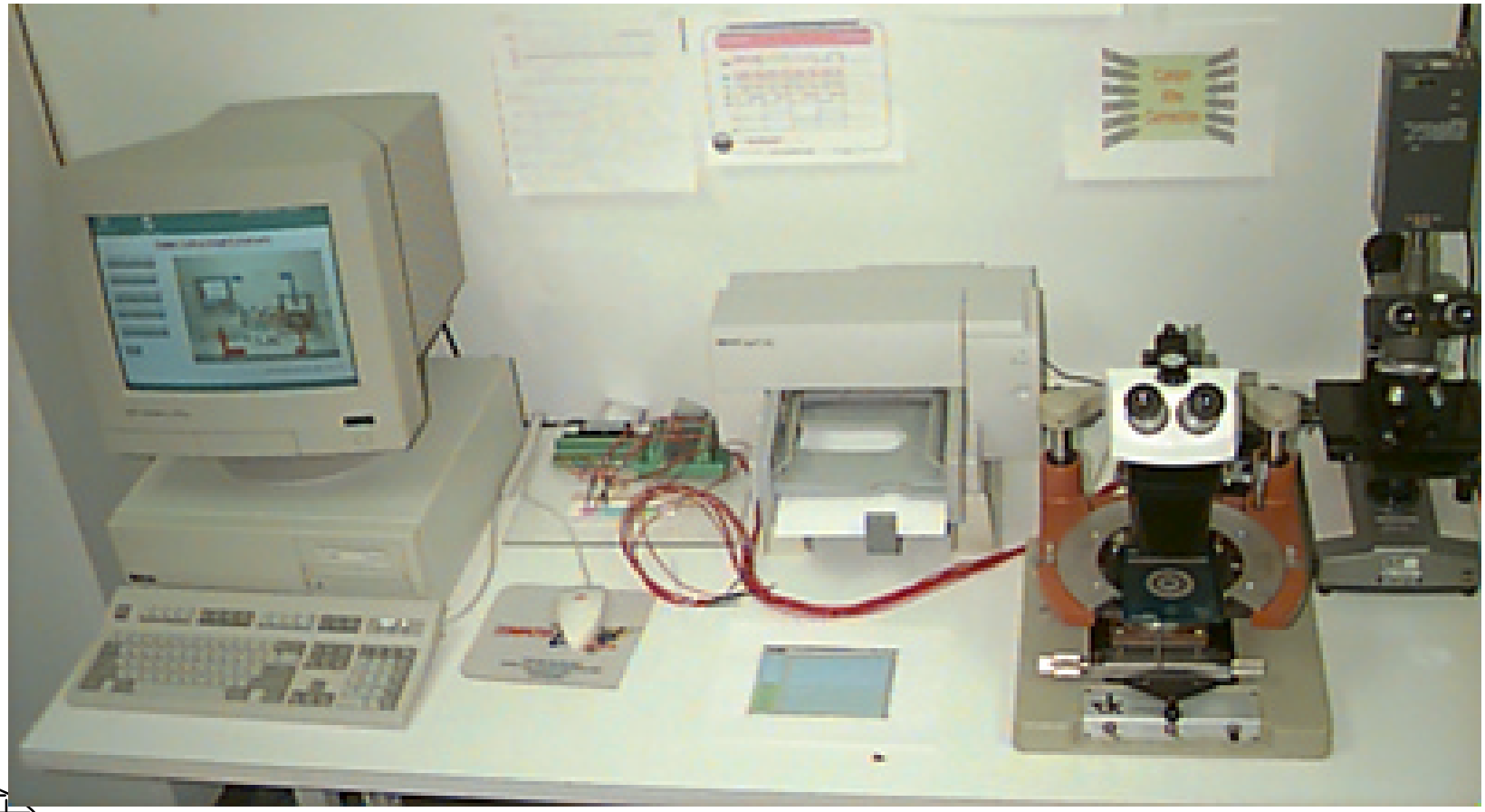
- 68-pin flat ribbon cable terminated with two 68-pin connectors
- 1 m length available
- Download PDFs for compatibility charts, more detailed descriptions, and ordering information

TBX-68



- Termination accessory with 68 screw terminals
- Easy connection of field I/O signals to 68-pinDAQ devices
- Mounted in plastic base; includes hardware for mounting on a standard DIN rail
- Dimensions: 12.50 by 10.74 cm (4.92 by 4.23 in.)
- Download PDFs for compatibility charts, more detailed descriptions, and ordering information

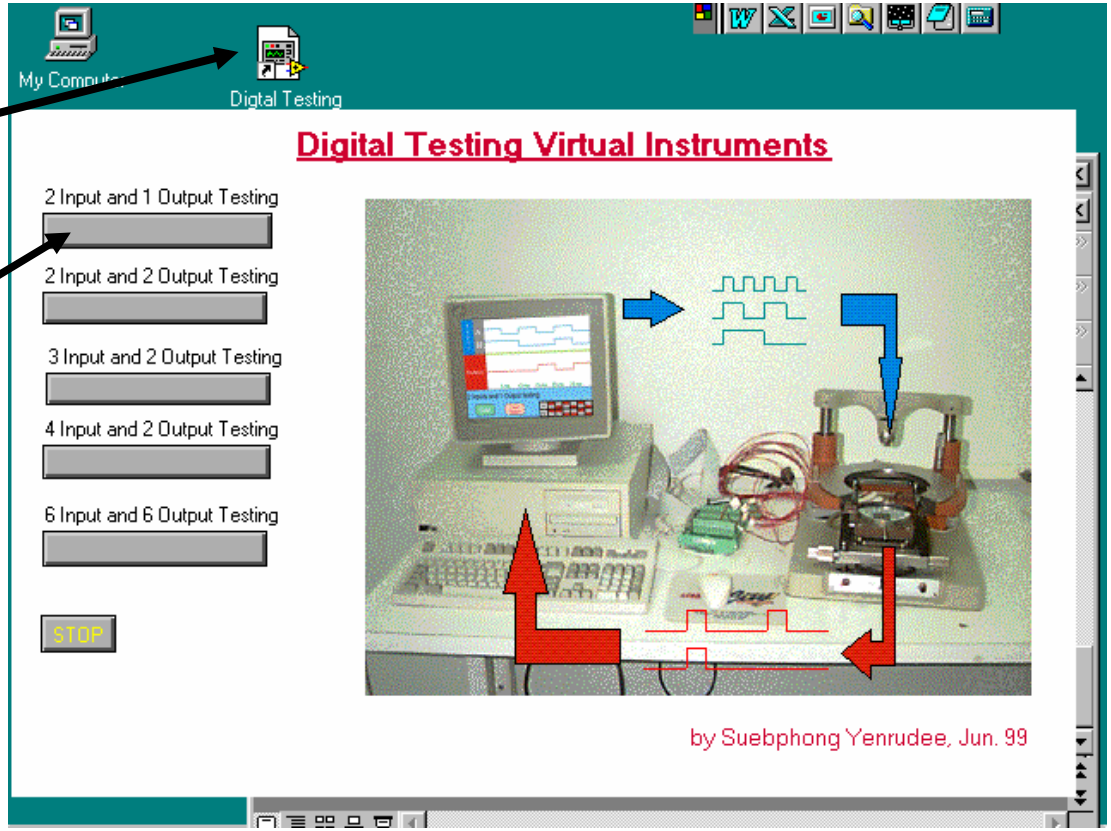
FINAL SYSTEM



CUSTOM SOFTWARE INTERFACE

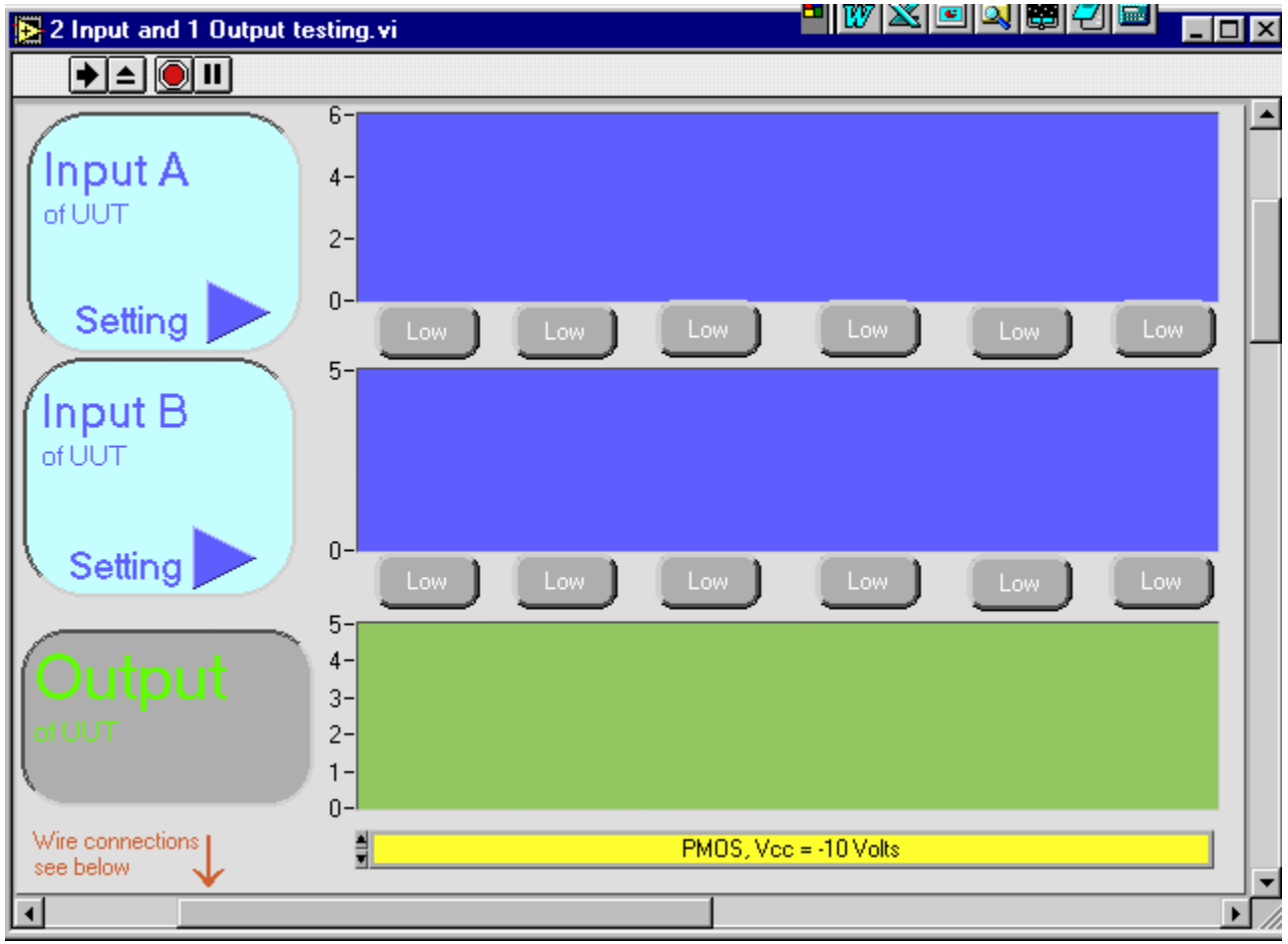
Click on digital testing icon to invoke the lab view software and this main menu.

Click to select the type of test you wish to run.



MAIN MENU

TESTING TWO INPUT ONE OUTPUT LOGIC GATES



FOUR CHOICES FOR SUPPLY VOLTAGES

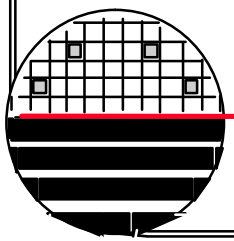
CLICK TO SELECT ONE

PMOS, Vcc = -10 Volts

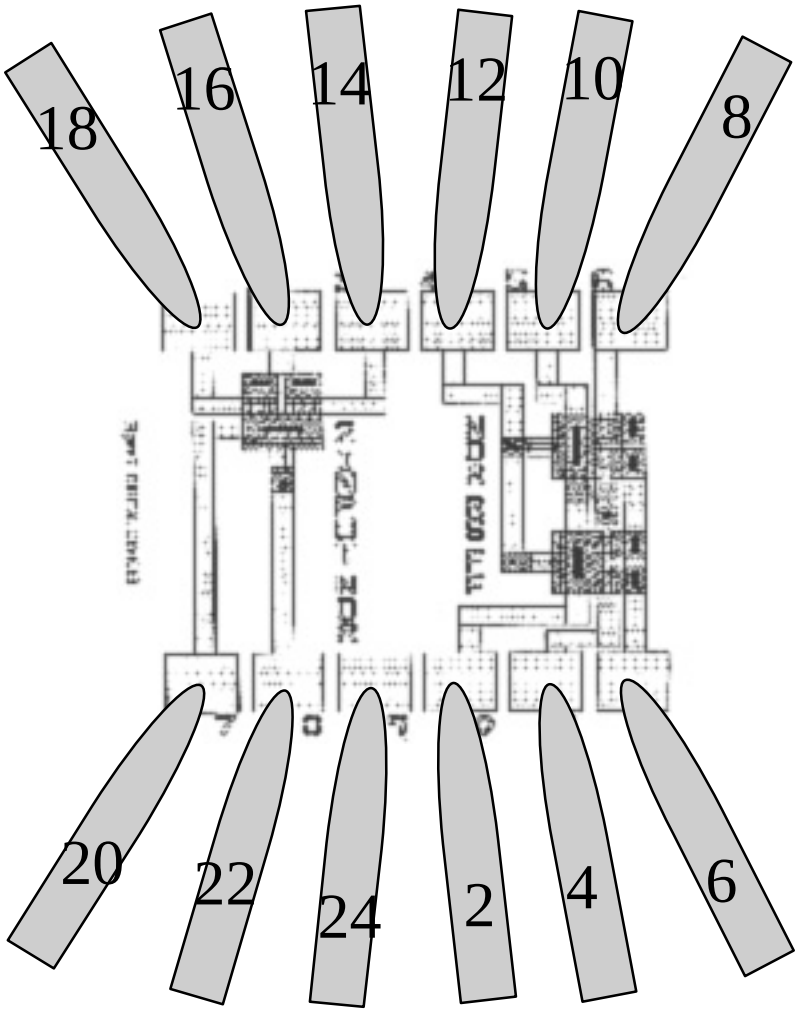
CMOS/TTL Vcc = +5 Volts

NMOS, Vcc = +10 Volts

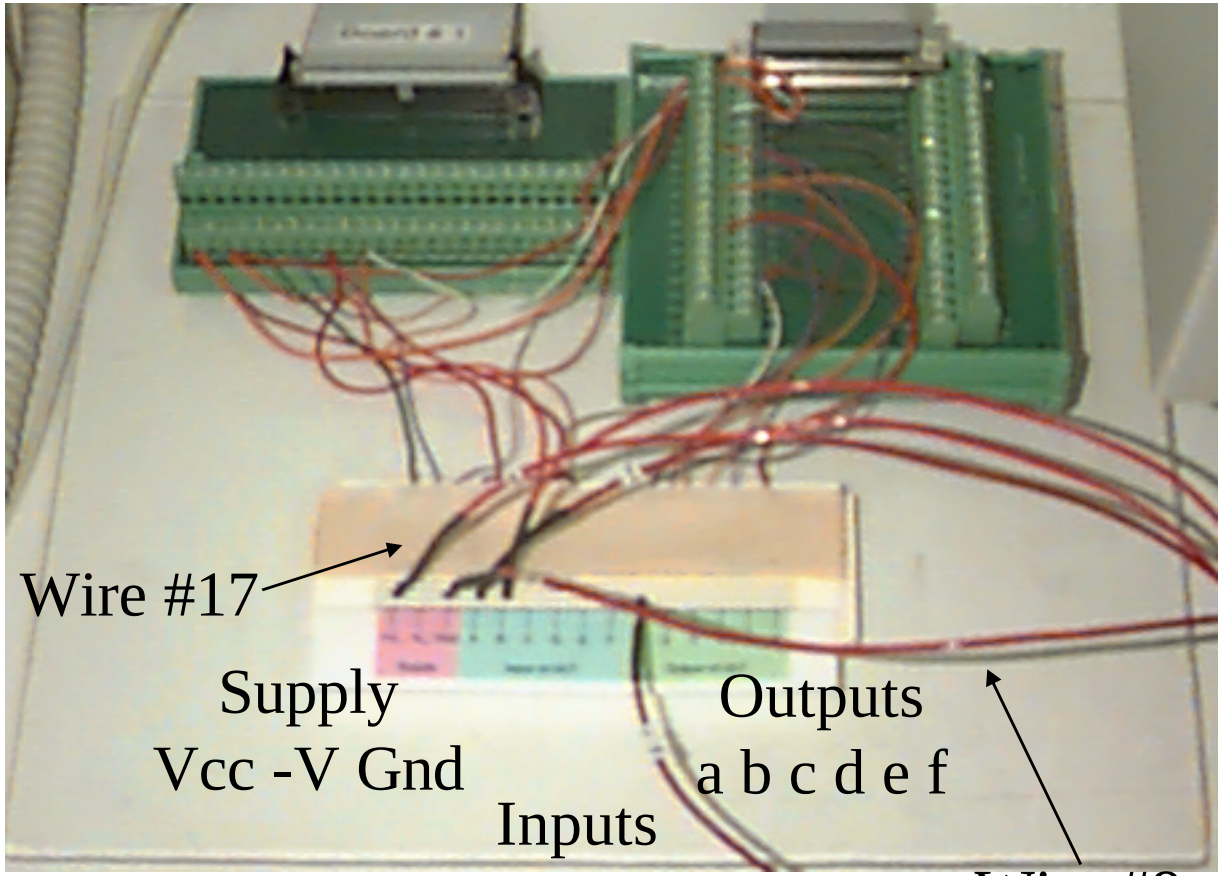
ANALOG, Vcc = +5 Volts, Vdd = -5 Volts



PROBE CARD/WIRE CONNECTIONS



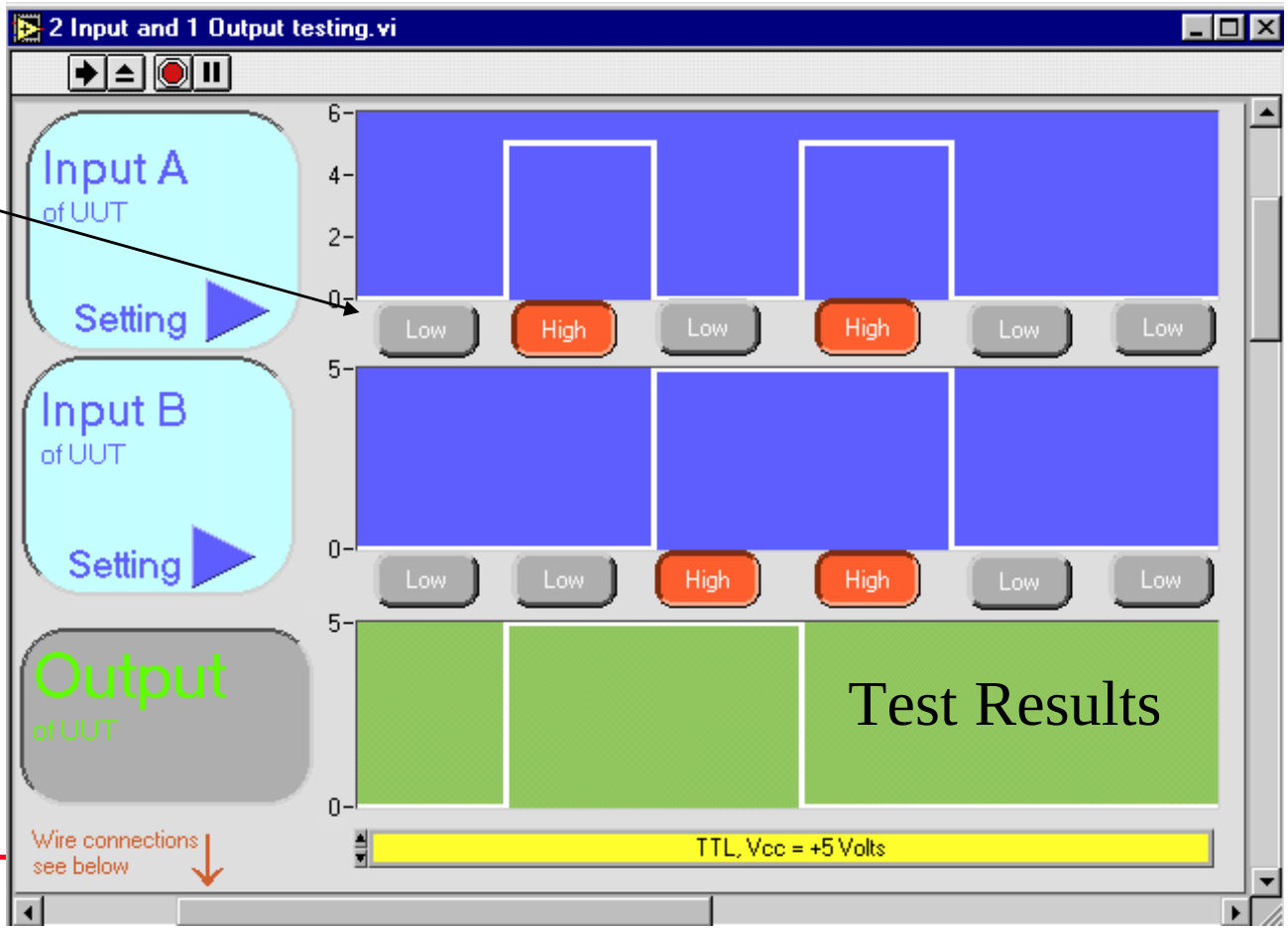
SWITCH MATRIX (MANUAL)



CMOS XOR GATE TESTING

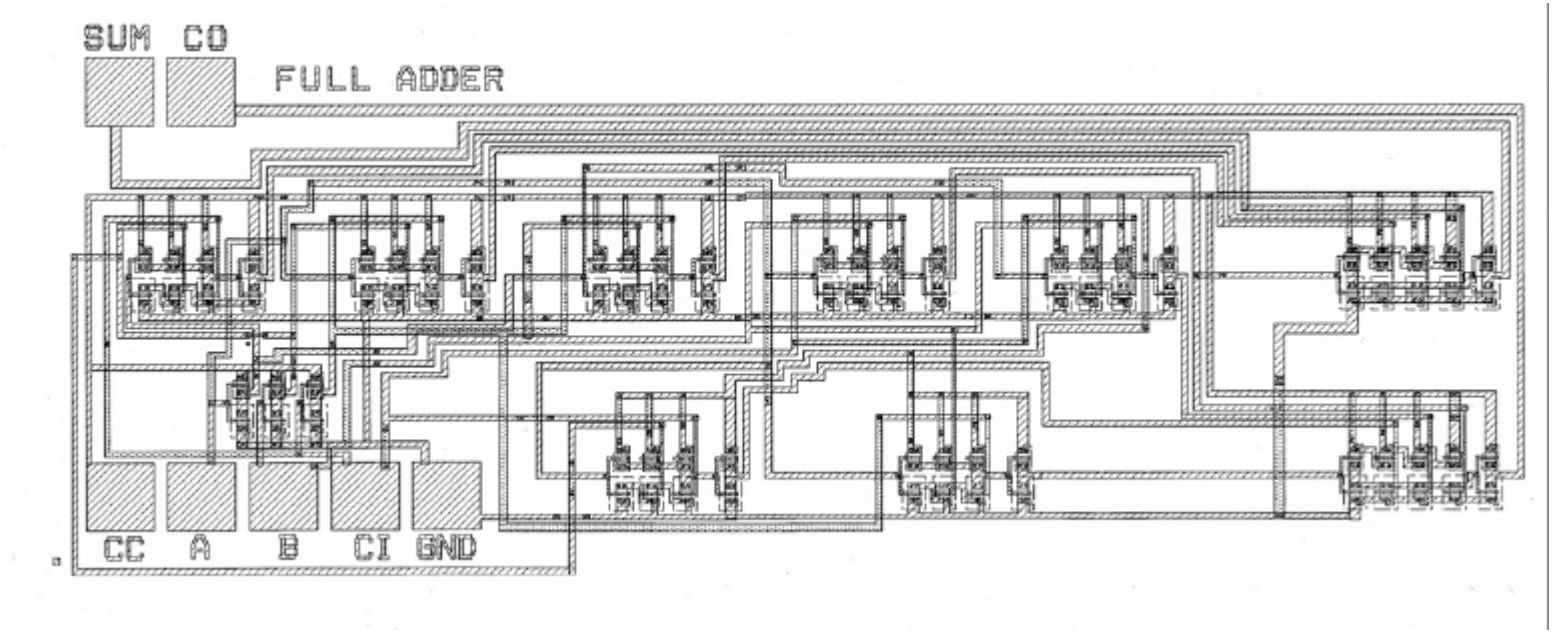
Click to Start Test
Stop Test

Click to Select When Output is High or Low



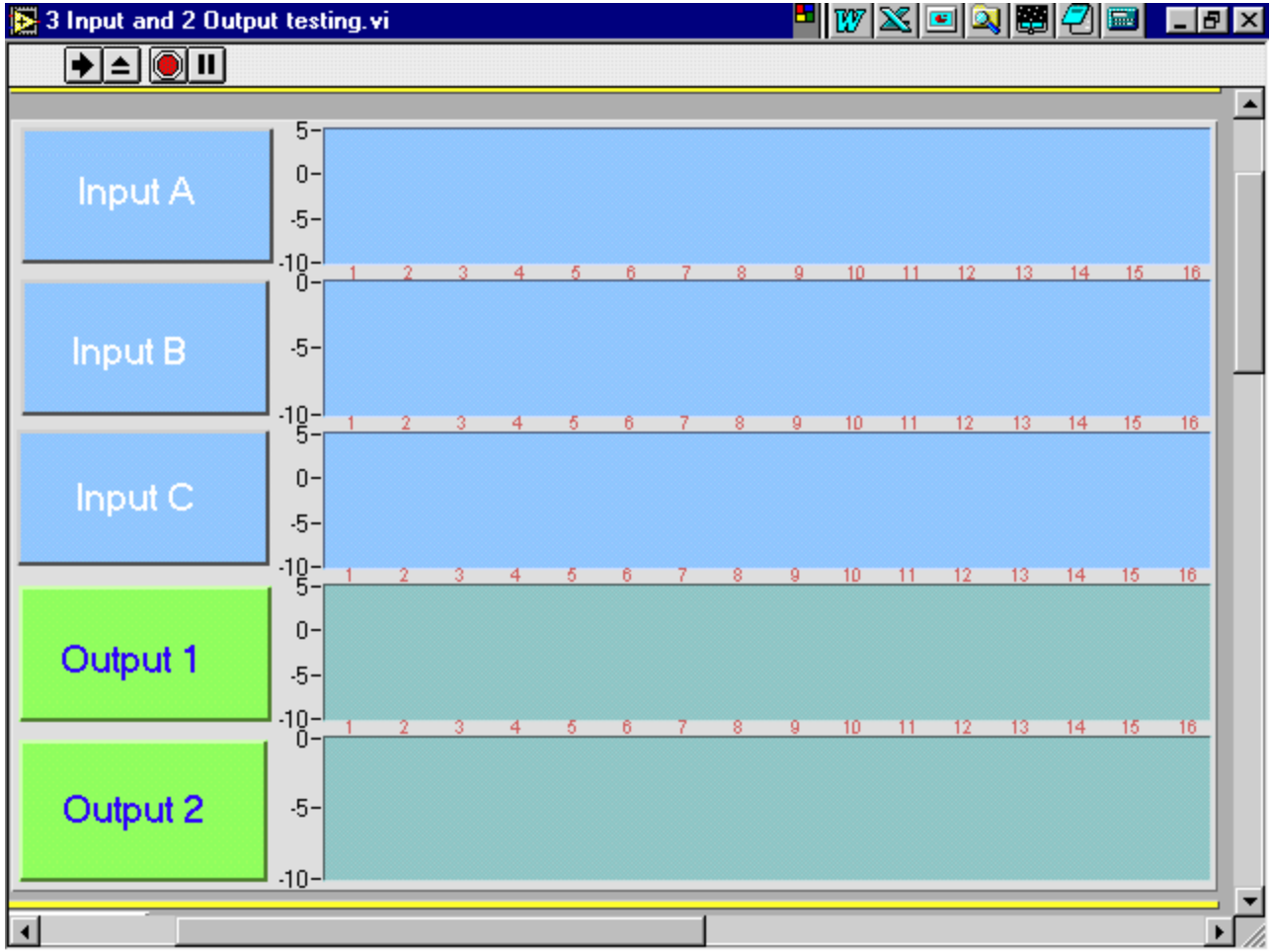
TESTING THREE INPUT TWO OUTPUT LOGIC GATES

3 Input OR, AND, NOR, NAND
Full Adder

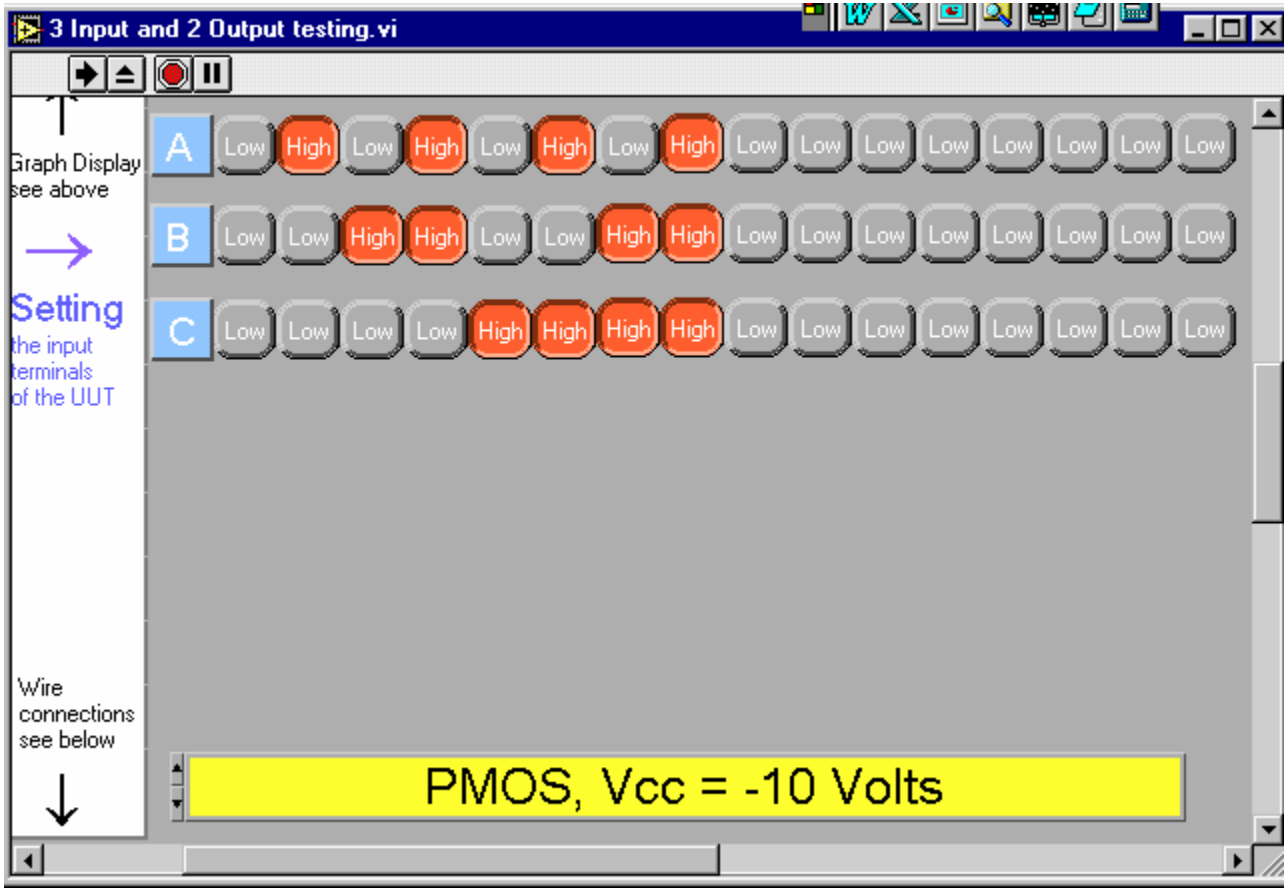


CMOS Full Adder

THREE INPUT TWO OUTPUT



DEFINE INPUT SIGNALS / SELECT SUPPLY VOLTAGE



ADDER TEST RESULTS

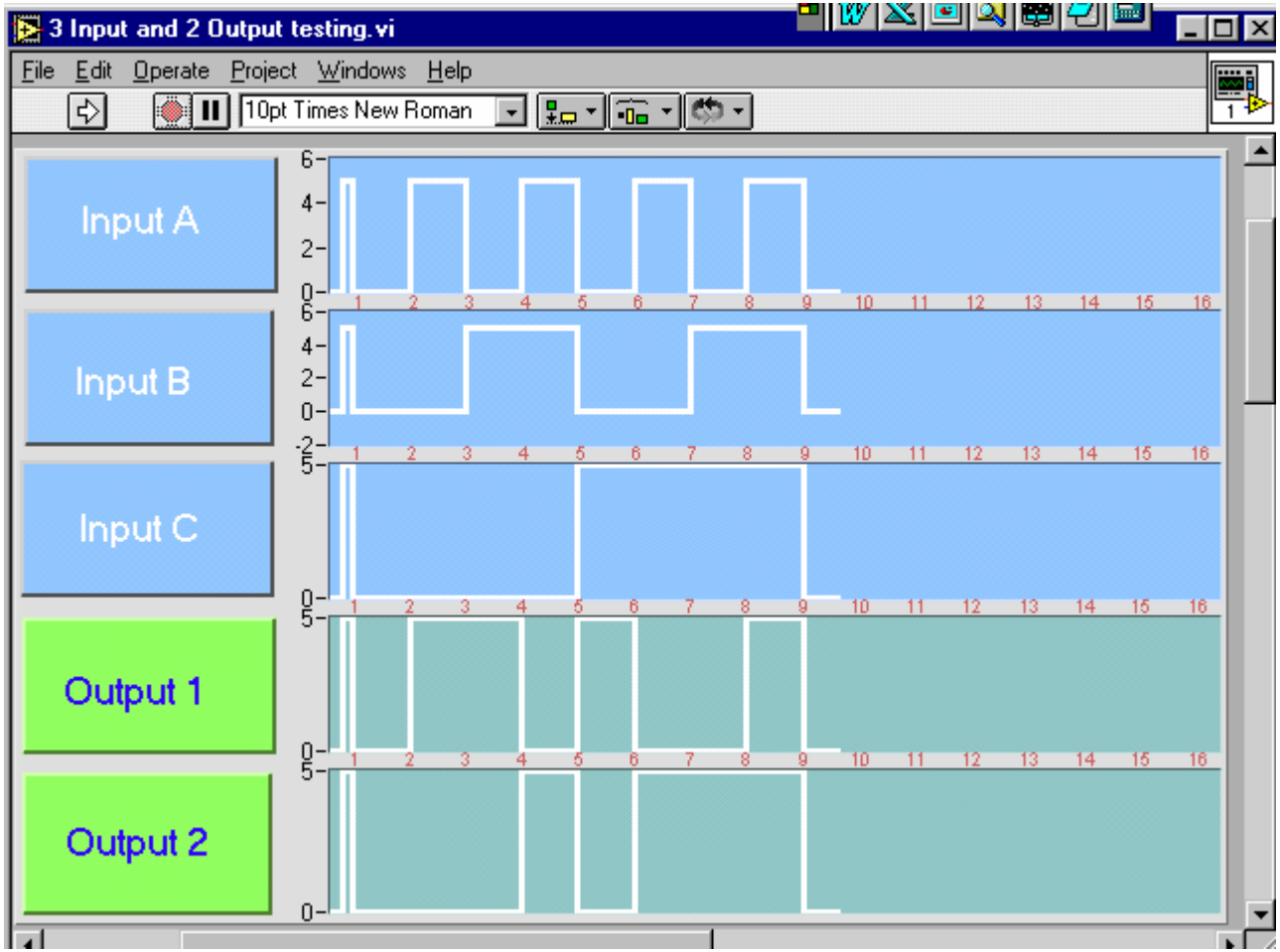
CARRY IN

B

A

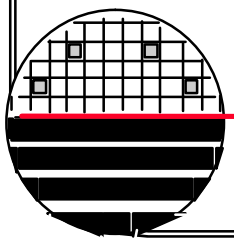
SUM

CARRY OUT

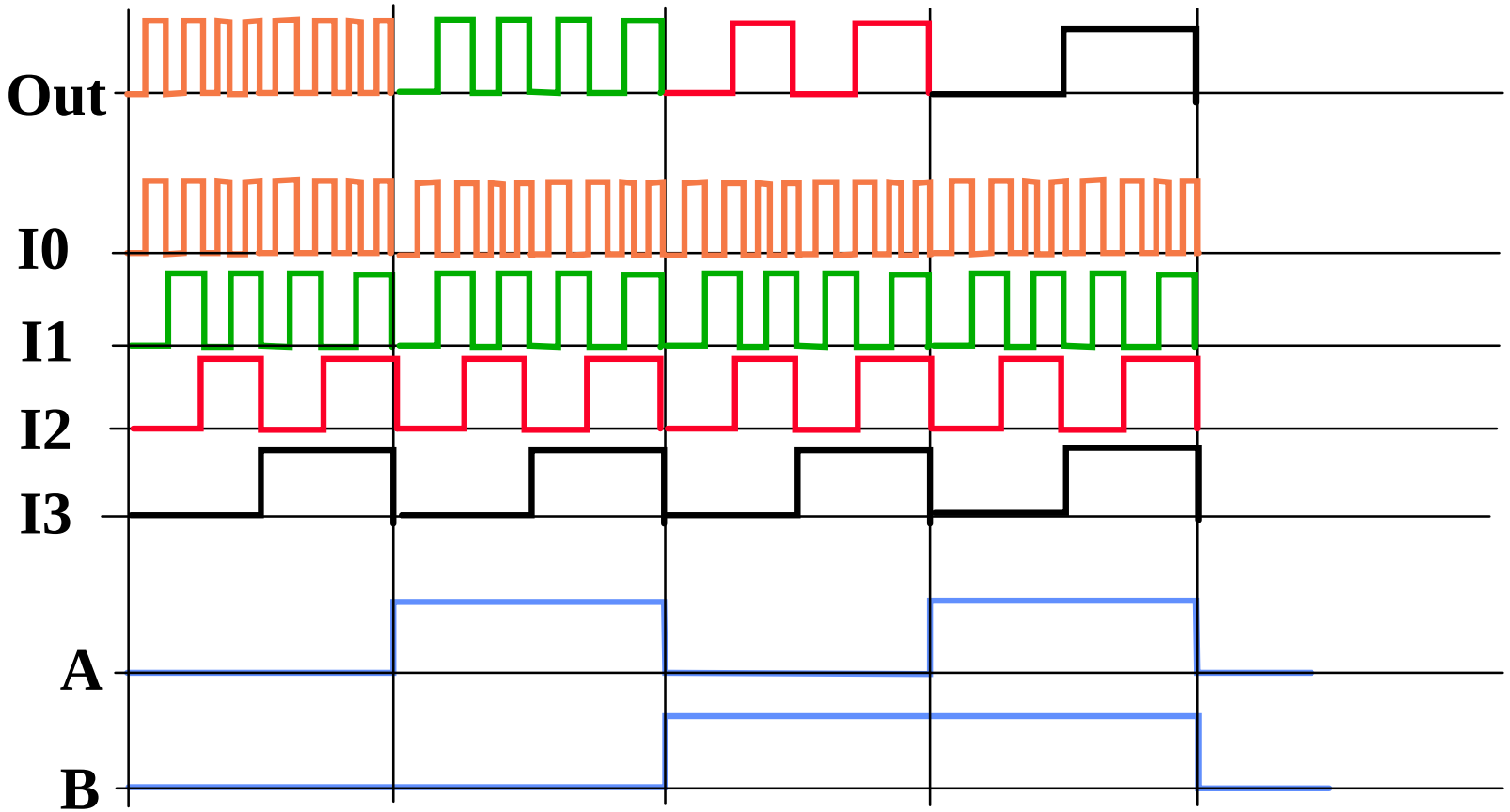


TESTING SIX INPUT SIX OUTPUT DEVICES

Multiplexer (6 inputs, 1 output)
Demultiplexer (3 inputs, 4 outputs)
Encoder
Decoder

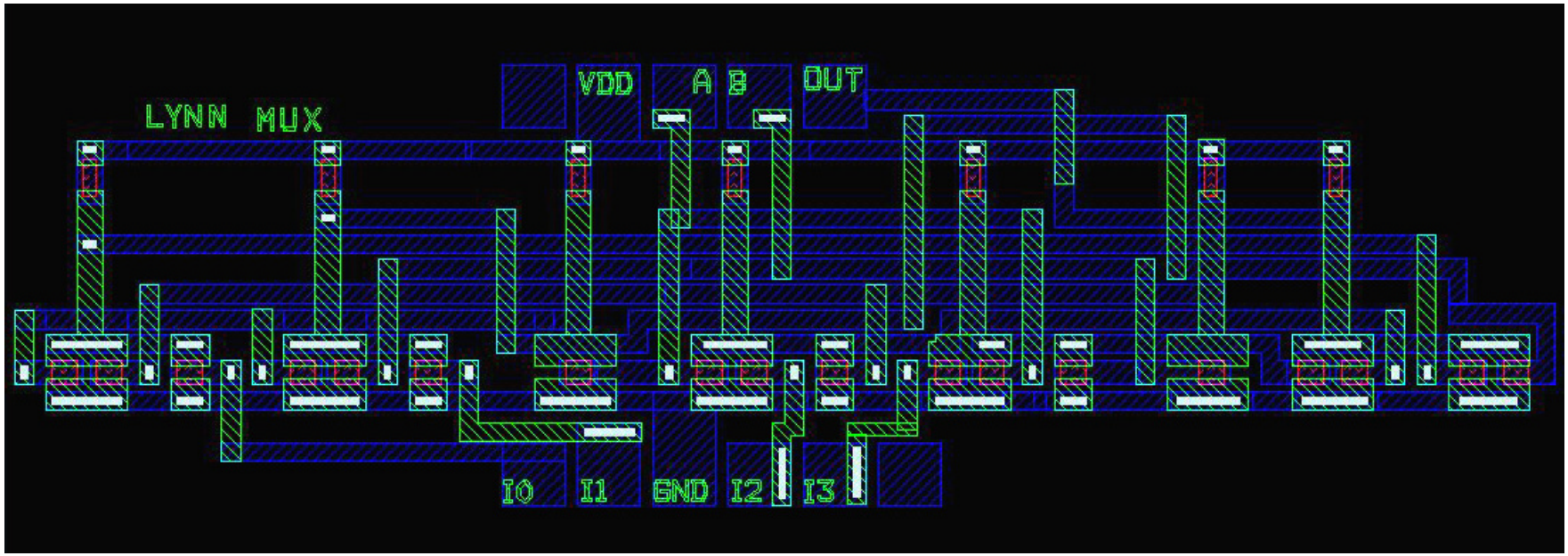


MULTIPLEXER TEST SIGNALS

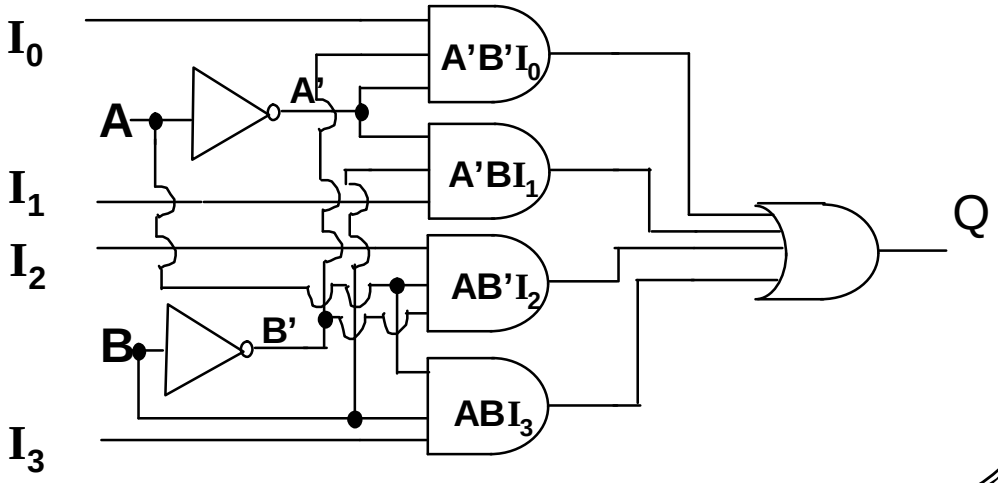


Input Signal I0, I1, I2 or I3 is directed to the output depending on the A and B select line values

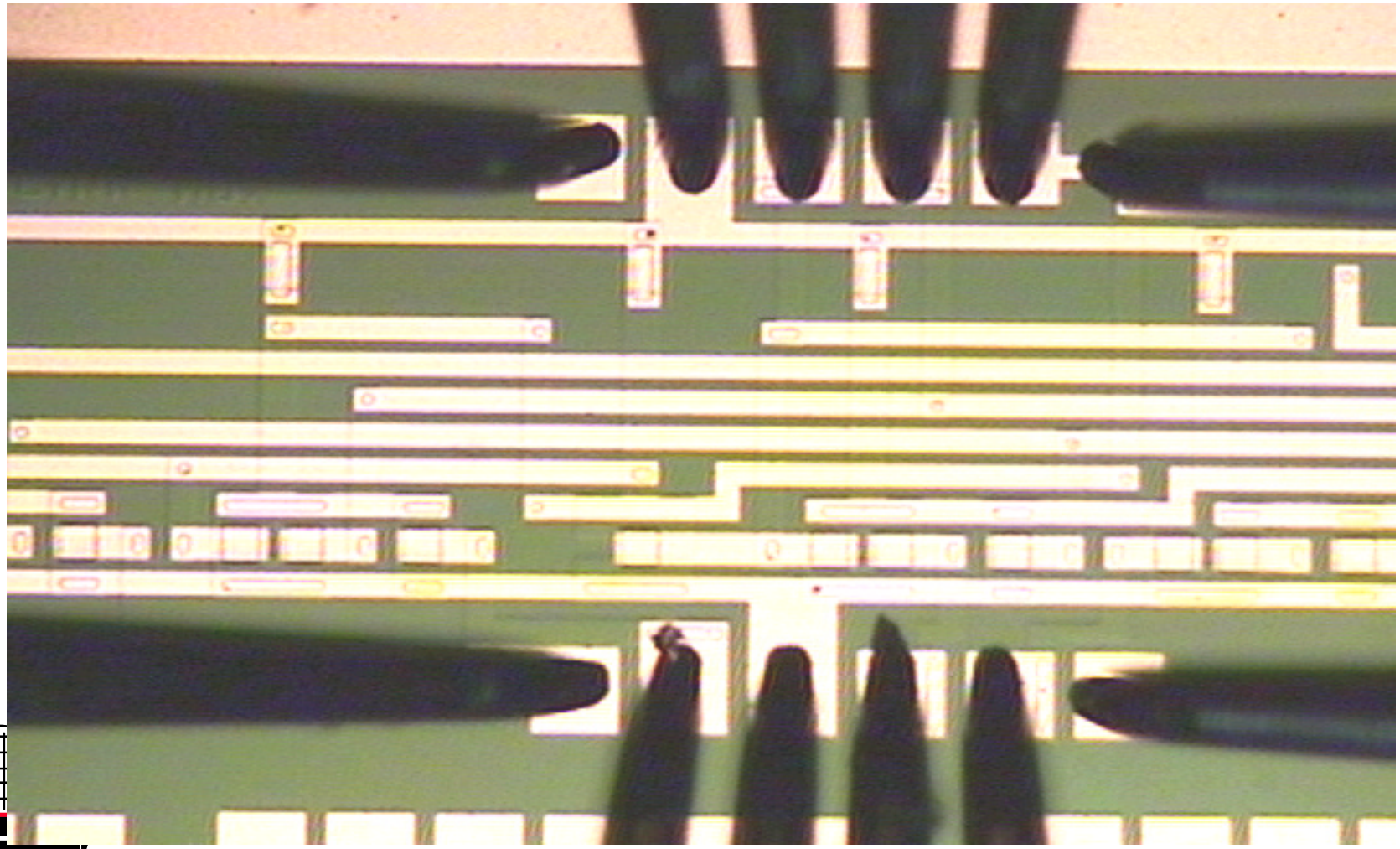
MUX LAYOUT AND GATE LEVEL SCHEMATIC



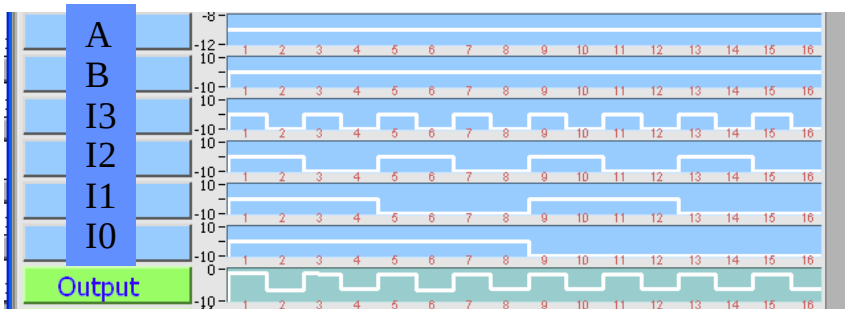
25 Transistors

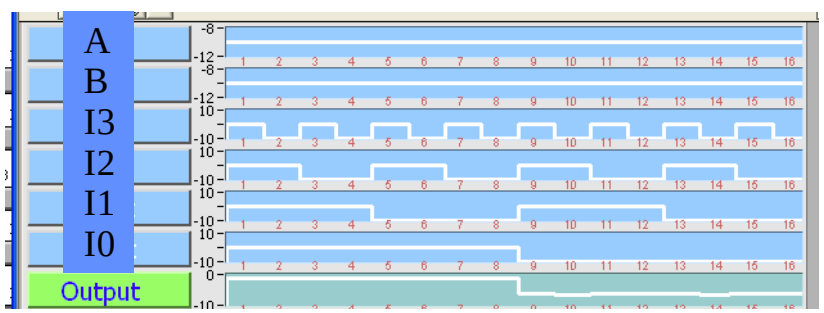


PMOS 4-INPUT MULTIPLEXER

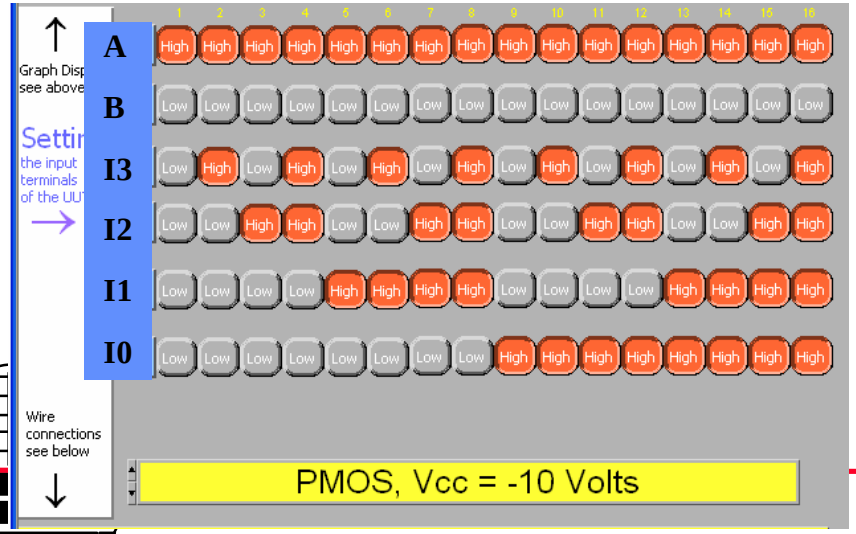


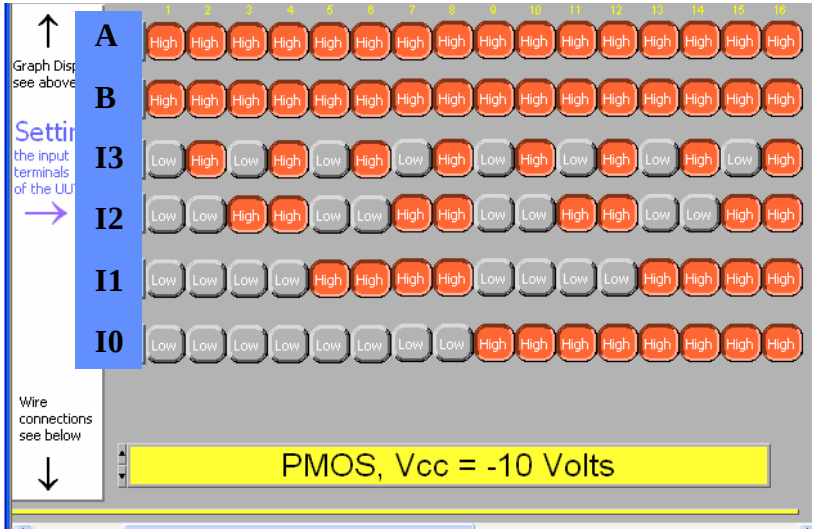
MUX TEST RESULTS



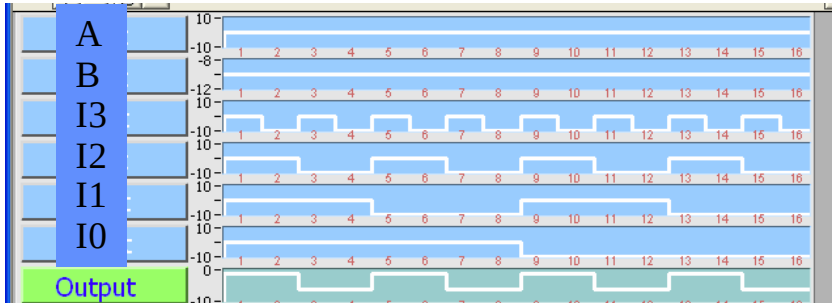


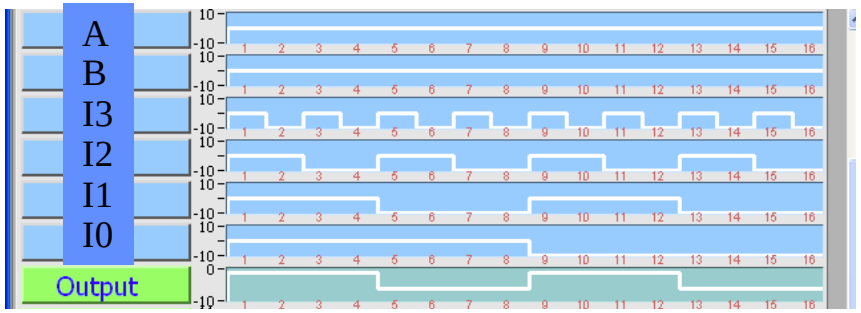
In PMOS logic low is 0 volts, logic high is -Vcc





MUX TEST RESULTS





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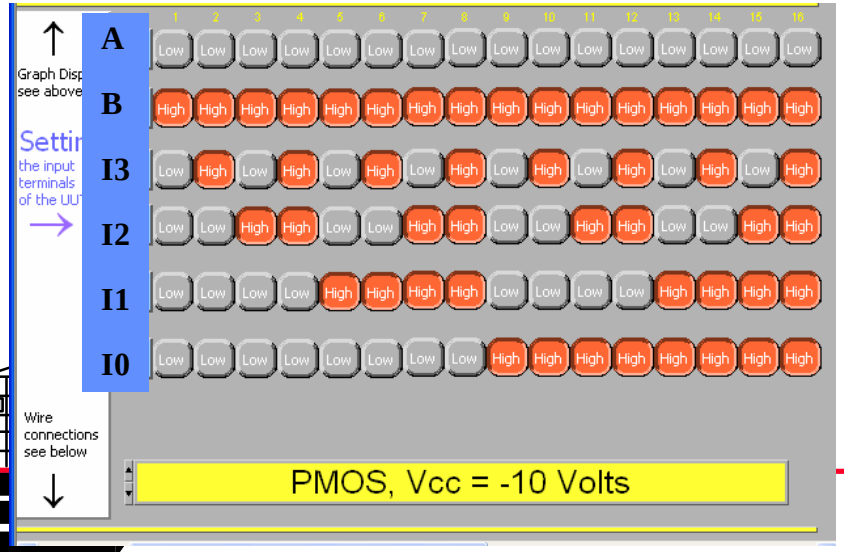
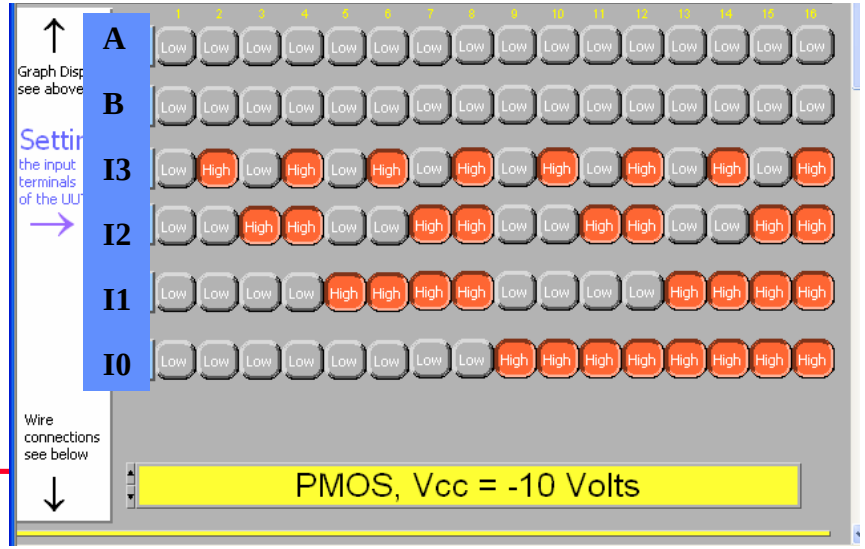
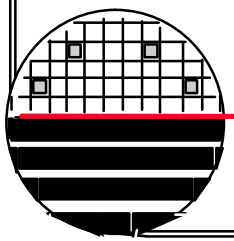




SUMMARY

1. The system works great.
2. Direct comparison between QUICKSIM output and tester output is possible.
3. Easy to use graphical interface. (Freshman to Graduate Students have used the system successfully)



REFERENCES

1. LabView Software, National Instruments, http://www.natinst.com