

Massachusetts Institute of Technology  
Department of Electrical Engineering and Computer Science  
6.111 -- Introductory Digital Systems Laboratory

## **NUBUS LABORATORY KIT**

For your pleasure and convenience, we have provided a portable, self-contained laboratory kit for each and every 6.111 student. This kit contains everything you will need to build that digital circuit you've always dreamed of.

### **Breadboarding Modules:**

There are six proto strip modules for mounting integrated circuits and other components. Each group of five (or four) contacts (running left to right) is internally bussed together, and every group is independent from every other.

The contacts on all proto strips accept leads from 0.015" (AWG 26) to 0.032" (AWG 20). However, they work best with AWG 22 wire; smaller diameter wires have a tendency to fall out. The spring loaded contacts may be damaged if you attempt to insert wire of larger diameter, so **don't do it**. Do **NOT** attempt to use wire larger than AWG 20. If you need to use a component with a larger wire, then solder a short piece of AWG 22 wire to it. Help is available at the Instrument Room desk.

The left hand proto strip is specifically designed for analog circuits. Immediately to its left is a distribution strip for +12 volts and -12 volts. Immediately to its right is a distribution strip for GND and +5 volts **ANALOG**. There is a separate AC power switch for these analog power supplies. Normally, when not using this proto strip, you should leave this AC power switch **OFF**.

Immediately to the right of the right hand five proto strips is a distribution strip for GND and +5 volts (**DIGITAL**). Note that the +5 volts (**DIGITAL**) and the +5 volts (**ANALOG**) are **NOT** connected. Do **NOT** connect these two +5 volt power supplies together. All power supply busses run vertically down the side of each strip.

Integrated circuits are installed on the center of a strip, leaving three or four contacts for each IC pin. Note that two of the five proto strips are narrower than the other three. Please keep this in mind when planning the location of ICs. Jumper wires, cut to the desired length from # 22 wire, are installed whenever needed. 3/8" of insulation should be stripped away from the wire for insertion into a contact.

Resistors, capacitors, and diodes may be placed where needed. When inserting components, especially integrated circuits, be careful not to break the pins. The pins of new integrated circuits will usually be fanned out slightly, making insertion difficult.

Bend the pins **carefully** to make them perpendicular to the body of the IC by pressing the IC against a table top so that the IC fits easily in place.

There are three proto strips labeled with the ``3M" logo. The two vertical ones are bussed together on the printed circuit board and also connected to three connectors at the lower right and to two larger connectors at the right hand side of the kit. The signals on these two ``3M" strips are identical EXCEPT for the top three connections. Labels on the pc board are supplied which correspond to signals required for the HP logic analyzer termination adapters. Note that these do **NOT** correspond to actual pin numbers on connectors L1, L2, and L3.

Ribbon cables are available for interconnecting kits via the two 50 pin connectors K1 and K2 on the right hand side of the kit. All of the even numbered pins on K1 and K2 are grounded. The wiring for connectors K1 and K2 is given in the following table.

### PROTO BOARD - KIT CONNECTORS

#### PIN ASSIGNMENTS FOR K1 and K2

ALL EVEN PINS (2, 4, ... , 50) ARE GND

Pin	K1	K2
49	L1-0	L2-8
47	L1-1	L2-9
45	L1-2	L2-10
43	L1-3	L2-11
41	L1-4	L2-12
39	L1-5	L2-13
37	L1-6	L2-14
35	L1-7	L2-15
33	L1-8	GND
31	L1-9	L3-0
29	L1-10	L3-1
27	L1-11	L3-2
25	L1-12	L3-3
23	L1-13	L3-4
21	L1-14	L3-5

19	L1-15	L3-6
17	GND	L3-7
15	L2-0	L3-8
13	L2-1	L3-9
11	L2-2	L3-10
9	L2-3	L3-11
7	L2-4	L3-12
5	L2-5	L3-13
3	L2-6	L3-14
1	L2-7	L3-15

### **Power supplies:**

The kit contains internal regulated power supplies for three voltages bussed to the power distribution proto strips. The +5 volt DIGITAL supply is a switcher rated at 8 amperes, and is used for powering digital IC's and the indicator lights. A linear power supply is used to provide the +12 volts and -12 volts for ANALOG circuits and the +5A ANALOG supply is provided by a separate voltage regulator powered by the +12 volt supply. The +12 and -12 volt supply is rated at 1.5 amperes. The +5A supply can supply about 1 ampere, but bear in mind that any current supplied by the +5A supply comes from the +12 volt supply. A separate (soldered) fuse<sup>2</sup> is provided for the +5A supply on the upper left corner of the pc board. It is best to reserve the +5A supply for analog parts even if you use the left hand proto strip for digital parts.

Switching power supplies generate RF noise. Low level analog circuits can be tested with the digital power supply turned off.

These internal power supplies can be damaged by wiring errors. Before turning on power, double check your wiring to make sure that no short circuits exist between any of the power busses. Unless you are using special components that require +/-12 volts, there should be no connection at all to these busses. These voltages will DESTROY 5 volt digital IC's such as the 74LSXX series in your kit. Double check the power supply connections to each chip before turning on the power. Reversed +5 and ground connections will most likely destroy the IC's. You should turn off the +/- 12 volt supplies (using the separate AC switch on the lower left) when they are not being used.

## **Nubus:**

The upper ``3M" proto strip provides access to a Nubus. The Nubus was originally provided as a possible way to add new capabilities. It has never been used as such. When not using the Nubus protocol, the following pins on the upper 3M proto strip should be left open:

/RESET

/1D0

/1D1

/1D2

/1D3

/TM0

/TM1

/PFW

/ACK

/START

/RQST

/NMRQ

/ARB0

/ARB1

/ARB2

/ARB3

Without a terminator card installed underneath the proto strip PC board (the normal configuration for 6.111) the ``Nubus" can be used for other purposes. Instead the CPLD and FPGA boards can drive AD0-31. See their separate write-ups. The switches and HEX LED display can be accessed by reading or writing to location 0xF3000000 when the switches and lights board is installed in slot 3 which is the normal position. When not using the Nubus protocol (the normal situation for 6.111) the signal ``NUHEX" should be grounded. When using another board via the NUBUS (ADxx), NUSW should be left

open. Beware of grounding NUSW if CPLD or FPGA boards drive any of the pins AD16-31. Avoid contention. Leave NUSW open. NUSW could be grounded to enable the switches to drive the right 16 NUBUS pins (AD 16-31). These signals are located at pins 1 and 3 (pin 2 is conveniently GND) of the left hand ``3M" vertical proto strip.

A standard Nubus clock which has a 25% duty cycle and a frequency of 10 MHz is provided. It is labeled /CLK and is located at the right hand end of the horizontal ``3M" proto strip.

### **HEX LED Display:**

An eight digit HEX LED display is provided. This can be accessed by a Nubus write transaction as mentioned above. Alternately, when the signal NUHEX is grounded, the 32 bit register that drives this display can be loaded via the 32 lines /AD31 through /AD0 (The LSB, /AD0 is the right hand bit). The high and low half-words (16 bits each) are clocked respectively by the signals /HHEX and /LHEX which are located at the left hand side of the horizontal ``3M" proto strip. When not using the Nubus, it is convenient to wire /CLK to both the /HHEX and /LHEX so that signals wired to the /AD0-31 lines are immediately displayed by the HEX LEDs. Remember that the signal NUHEX must be grounded for the HEX LEDs to be used in this way.

### **Indicator Lamps:**

There are eight LED lamps (L7-L0) which are internally wired as shown in Figure 1. See the labels at the upper left of the kit. When the lamp contact point is open circuited or at ground potential, or logic 0, the lamp is dark. When the lamp contact is at or above approximately 3.3 volts, current flows through the LED (with a built in resistor) and the lamp is lit.

### **Switches:**

There are 16 SPDT (Single Pole, Double Throw) switches. Switches S31-S28 (the left hand four) are momentary contact push button switches. Switches S27-S16 (the right hand twelve) are toggle switches. All switches are debounced with latches, so that multiple transitions are not generated when the switch position is changed. The pushbutton switches are wired as shown in Figure 2. The toggle switches are wired as shown in Figure 3. The switches can be accessed by a Nubus read transaction as mentioned above. The TTL outputs of the switches are always available at the upper left of the kit as labeled on the PC board. Note that the push button switches have both TRUE and COMPLEMENT outputs available.

### **Tools:**

Wire cutters, wire strippers, needle-nose pliers, IC extractor, and a logic probe are included.

## **Components:**

A variety of discrete components are available in the lab. Integrated circuits are supplied on a conducting foam carrier with an associated map of their locations. Please replace ICs according to the map to make it easy to find ICs and to facilitate re-stocking. These components will satisfy nearly all of your circuit requirements for the assigned labs in 6.111.

## **Bypass Capacitors:**

Large current spikes result when the outputs of digital IC's change state. The effect of these spikes can be ameliorated by placing a medium-value capacitor between +5 and ground in close physical proximity to the IC's. This bypass capacitor acts like a local reservoir for the transient current. The bypass capacitor needs to be physically close to the chip because of the inductance associated with the breadboard strip busses. Each power supply distribution strip is bypassed with a .1 micro-farad capacitor at the top and bottom. This should provide sufficient bypassing, but in case of suspected problems, you may want to add another 0.1 micro-farad bypass capacitor in the middle of each power strip.

## **Wire:**

Number 22 solid conductor wire is available in the lab.

We recommend using RED wire for +5 volts, BLACK wire for GROUND, and other colors for signals.

## **Wiring Circuits:**

Neatness and orderliness in wiring circuits are extremely important. We really don't expect you to believe this at first. Many students before you have learned this lesson the hard way. They have wired in a sloppy manner and have not been able to get their circuit to work until they ripped out the original wiring and re-did it neatly. A photo of a second wiring of part of a project is shown on page A-1. You should follow its style in wiring your circuits.

## **Static:**

MOS IC's are particularly susceptible to damage by static discharges. Please be careful to ground yourself before touching the IC. Keep the IC's in conductive (black) foam.

## **Integrated Circuit Pin Assignments:**

Pin connection data for most IC's supplied in the 6.111 kit follows. For electrical and other information, refer to the **TTL Data Book** by Texas Instruments, Inc. It is your primary source of information for understanding the electrical and logical characteristics

of the ICs. You should read the data sheet carefully before using a given IC for the first time. Data is not included for:

- AD558 D to A converter
- AD670 A to D converter
- 28F256A 32K x 8 Flash PROM
- 6264 8K x 8 SRAM
- 20V8 PAL
- 22V10 PAL

Supplements will be issued on these integrated circuits just before you need to use them. PLEASE DO NOT USE THEM UNTIL YOU RECEIVE THE SUPPLEMENT. They are expensive components, which can be easily damaged if not used properly.

### **Crystal Oscillators:**

The crystal oscillators supplied can be easily DESTROYED if the power wiring is reversed by plugging it in UPSIDE DOWN. Please be careful as we lose a number of these every term! Also note that the output is rated for only 1 TTL load.

### **CPLD and FPGA Boards:**

CPLD and FPGA boards can drive AD0-31. Avoid contention. Read their separate write-ups before using them.