aculty of Science and Engineering Technology
Higher Education Division

Laboratory Manual
EEE20001
Digital Electronics Design

Version date 10 March 2020

SWINBURNE UNIVERSITY
OF TECHNOLOGY

Laboratory Program

The laboratory program is intended to re-enforce the material covered in lectures and tutorials by a practical program involving design and implementation of digital circuits. This re-enforcement will be a natural outcome of individuals completing the design work, debugging the resulting design implementations and finally obtaining the desired operation. This process involves a fair amount of effort, but the reward is a much better understanding of the material and the gaining of some real-world abilities – especially fault finding and debugging!
I urge all students to put in the required effort rather than seeking the obvious short cuts.

- The laboratory program is completed by groups of 2 students with only a single submission required from the group. To support the program, each group is provided with their own set of laboratory hardware. This allows a great deal of the work to be completed out of formal laboratory time. Both group members will be required to sign for this equipment and return it in good order at the completion of the laboratory program. **Results for the unit will be withheld until the equipment is returned.**

- You will also need to use Electronic Design Automation (EDA) software. This software is only available for student use on campus in the AD207, AD208 laboratories and on limited machines in the library. These first two are general access laboratories and students are expected to access the labs out of scheduled class time. The required software may also be obtained for private use. Details are available from Canvas.

- The laboratory program consists of 4 single laboratory sessions and a project which extends over 3 laboratory sessions.

- The first 4 laboratory exercises require submission of a work sheet at the completion of the laboratory session. This sheet is to be submitted to the laboratory supervisor. The work sheet has required preliminary work that must be completed before entering the laboratory. Various stages of the work sheet require initialling by the laboratory supervisor to record correct completion and demonstration of work done. It is the student's responsibility to ensure that the demonstration and recording of such occur during the laboratory session. The sheet should be handed in at the completion of the session or otherwise recorded by the laboratory supervisor. **Failure to complete preliminary work before the laboratory session may result in the student(s) being excluded from the session and receiving no marks.**

- The assessment of laboratory exercises will be based upon demonstration of work, understanding of operation and written submissions. Laboratory work will require an individual oral presentation of results.

- The VHDL project is completed over 3 laboratory sessions but again it is expected that much of the work will be completed outside of the formal sessions. These sessions should be viewed as an opportunity to ask questions and obtain help with specific problems. The project requires a single written report for each laboratory group. Note however, that individual assessment will still occur in the laboratory sessions. The practical demonstration is to occur during scheduled laboratory times. Submissions will not be accepted by email or electronic form.

- Late submissions for laboratory work without adequate reason and prior arrangement may attract zero marks. Adequate reason will usually be similar to an unanticipated medical problem extending for a significant time

Closed Footwear must be worn in the laboratory. Students wearing open-toed shoes or thongs will be asked to leave the laboratory and will be unable to complete the work.

Rules for EEE20001 Laboratories

Section 1: Rules for dealing with equipment during laboratory sessions

- Never build or alter a circuit while power is applied to it.
- Do not connect power to a circuit until the circuit is finished and you have carefully checked your work.
- Keep your work area dry. Keep any food and drink bottles in your bag and well away from the work bench.
- Make sure you know where the safety equipment in the laboratory is located (such as the fire extinguisher, first-aid kit, emergency power cut-off button (where installed) and the nearest phone and list of safety personnel).
- Faulty equipment or equipment with suspect wiring or other safety concerns must be switched OFF at the power point immediately and reported to the demonstrator
- Equipment that does not have a current electrical tag must not be used-report this to the technical staff or supervisor
- On completion of experimental work all equipment is to be switched off, equipment and leads stored away appropriately, and bench areas left in a tidy and safe state.

Section 2: Conduct requirements during laboratory sessions

The University executes safety drills without warning. Be prepared to follow instructions from university staff and/or wardens to evacuate the building in a safe and orderly manner.
All students are expected to respect the rights and sensibilities of their fellow students and teaching staff. The University has rigorous anti-discrimination and harassment policies and procedures.
The following specific safety procedures must be followed in the laboratory:

- Open-toed shoes (including thongs, or sandals etc., or bare feet) are not permitted in the Electronics laboratory, and students may be excluded if they have inappropriate or inadequate footwear.
- Drink (including water from drinking bottles) or food is not permitted in the laboratory.
- Sitting on laboratory benches is prohibited.
- You should never run in the laboratory. Make sure bags and other articles do not obstruct the exits or constitute a tripping hazard. Place them as indicated by your supervisor or the technical staff.

Section 3: Relevant Safety Information for laboratory sessions

- First Aid

  If you, or someone you are with, require first aid at any time while you are in the labs, please contact your laboratory demonstrator and/or the laboratory technician immediately or contact a First Aid officer as shown on the ‘First Aid’ poster near the telephone or near the entry. If you are unable to find a staff member, you must ring 9214 3333, the emergency number for Campus Security who are First Aid qualified. You might also need to ring the Campus Medical Centre on 9214 8483.

  If you yourself are feeling unwell or dizzy when participating in an experiment, stop immediately, sit down and ask someone to notify the demonstrator or laboratory technician.

  Any accident must be reported to the demonstrator or laboratory technician.

Laboratory Equipment

The following Equipment is provided:

- Digital Logic Board
  - This incorporates: Switches, LEDs, Clock, Dice, Traffic Intersection and Stepper Motor modules.
- USB-C lead
- Bread-board wires
- CPLD module
- Power bridging PCB.
- Programming cable from baseboard to CPLD
- A selection of SSI and MSI integrated circuits and some discrete components.

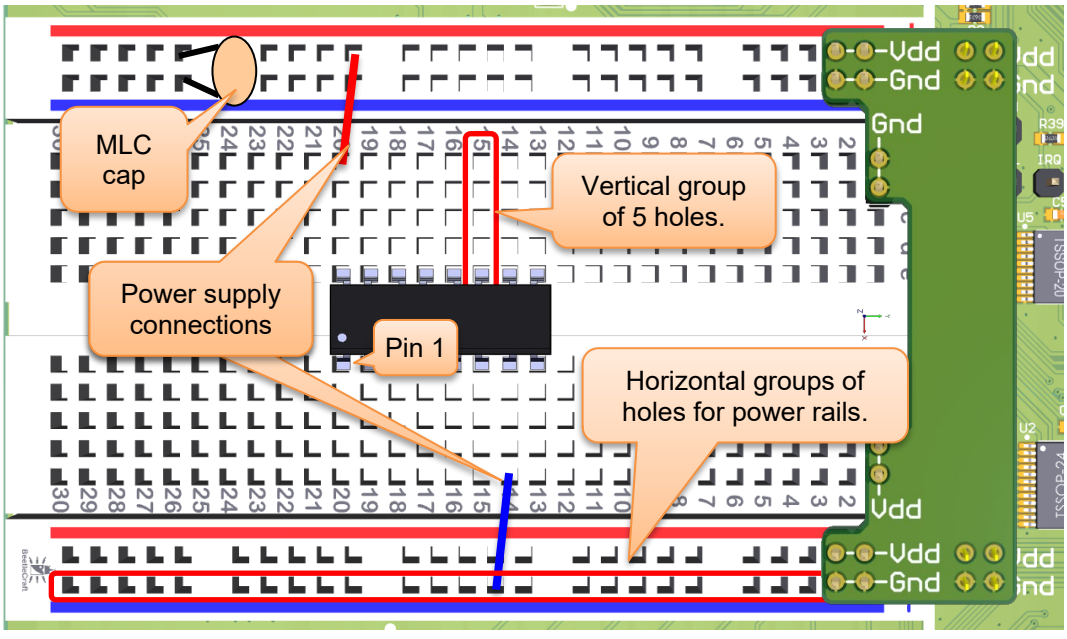
Use of this laboratory equipment is described in the following sections.

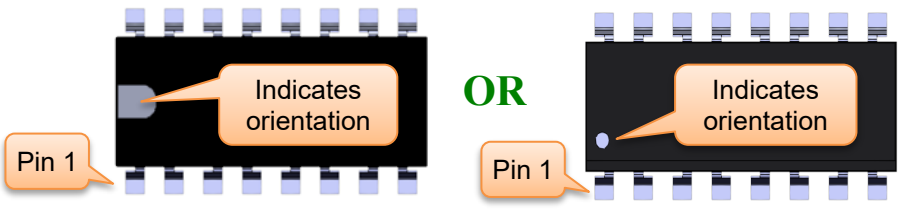
Prototyping Board

The prototyping board is attached to the baseboard but is electrically isolated from it. Connection to the power on the baseboard is made through a small PCB that bridges between the breadboard and baseboard as shown.

The breadboard has holes connected in vertical groups of 5 in the main part of the board and horizontal strips that extend for the width of the board at top and bottom. These provide convenient power supply locations and are indicated in red for Vdd and blue for Gnd. This allows access to the power rails from either side of the IC packages. It is also desirable to place two 100nF multi-layer ceramic (MLC) capacitors across the power supply rails to reduce noise.

The ICs are placed so that they straddle the channel in the middle of the board. When placing ICs in the board they should be spaced apart to allow easier removal by levering them up at both ends. Do not try removing them by hand as it will bend the pins and even cause injury. Yes - I have seen students with neat rows of holes in their fingers from the sharp pins

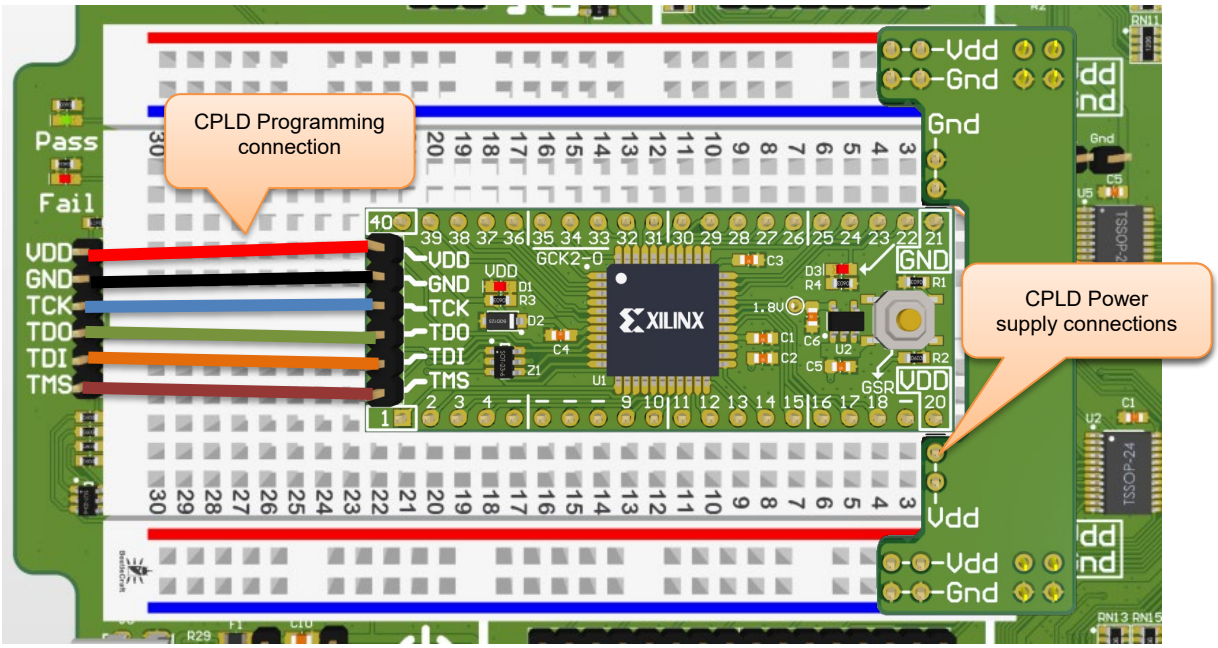




The CPLD should be placed so that its power supply connections match the inner connections on the small bridging PCB.

Do not try removing the CPLD by hand as it may bend the pins.

To remove the CPLD first remove the bridging board and the programming cable, and then lever the module up at BOTH ends in turn until it is released from the breadboard.



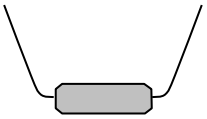
Important Warnings

- ✓ **Circuitry must be switched off before changing any wiring.**
- ✓ **It is important that all connections be made correctly and that they are carefully checked before switching on the circuit. This is especially true of the power supply connections for the ICs (Usually the corner pins p14/15 = Vcc, p7/8 = Gnd).**
- ✓ **Before changing the circuit, discharge any static electricity by touching an earth connection on the baseboard (bottom or top row of pins).**
- ✓ **ICs should be stored pressed into anti-static foam when not in use.**
- ✓ **The board should be stored in the anti-static bag when being carried.**
- ✗ **The plug-in modules should not be moved.**

Failure to observe these precautions may easily result in damage to the hardware!

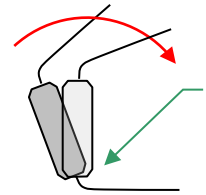
How to bend IC leads

It is necessary to bend the leads of the ICs before trying to insert them into the prototyping board. Use the method shown below or use the ***pin straighteners*** available in the lab sessions.

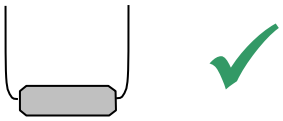


A new I.C. has leads splayed. The leads are normally bent parallel by automated placement machines before insertion in a PCB.

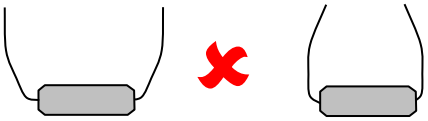
For our use, it is necessary to bend the leads manually as shown below.



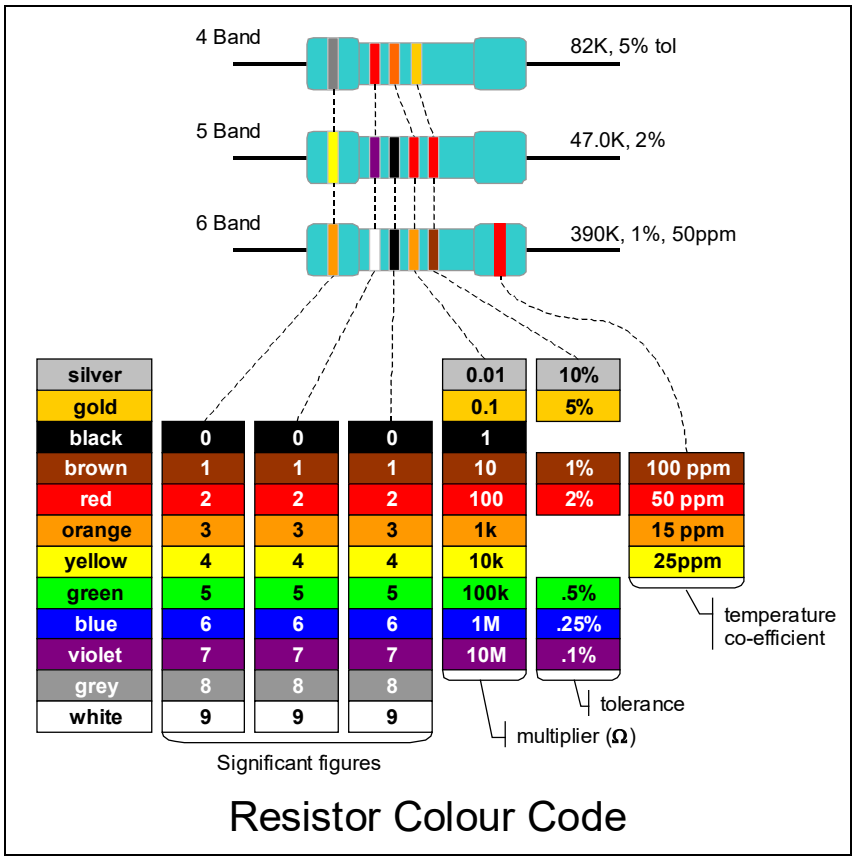
Rotate I.C. at shoulder against a hard surface – don't just push!



The I.C. leads should look like this. Bent parallel near the IC body.



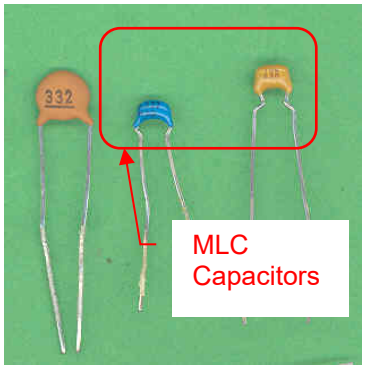
The I.C. leads should not be bent where they transition from wide to narrow width.



Resistor Colour Code

Light emitting diode (LED)

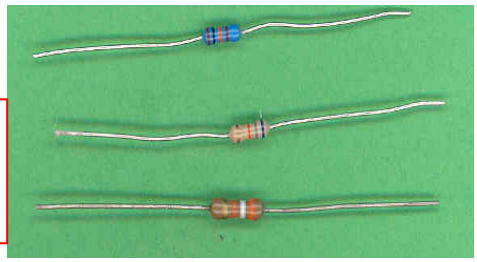
Anode (+ve) is (usually) the longer lead



Ceramic Capacitors

Aluminium Electrolytic Capacitor

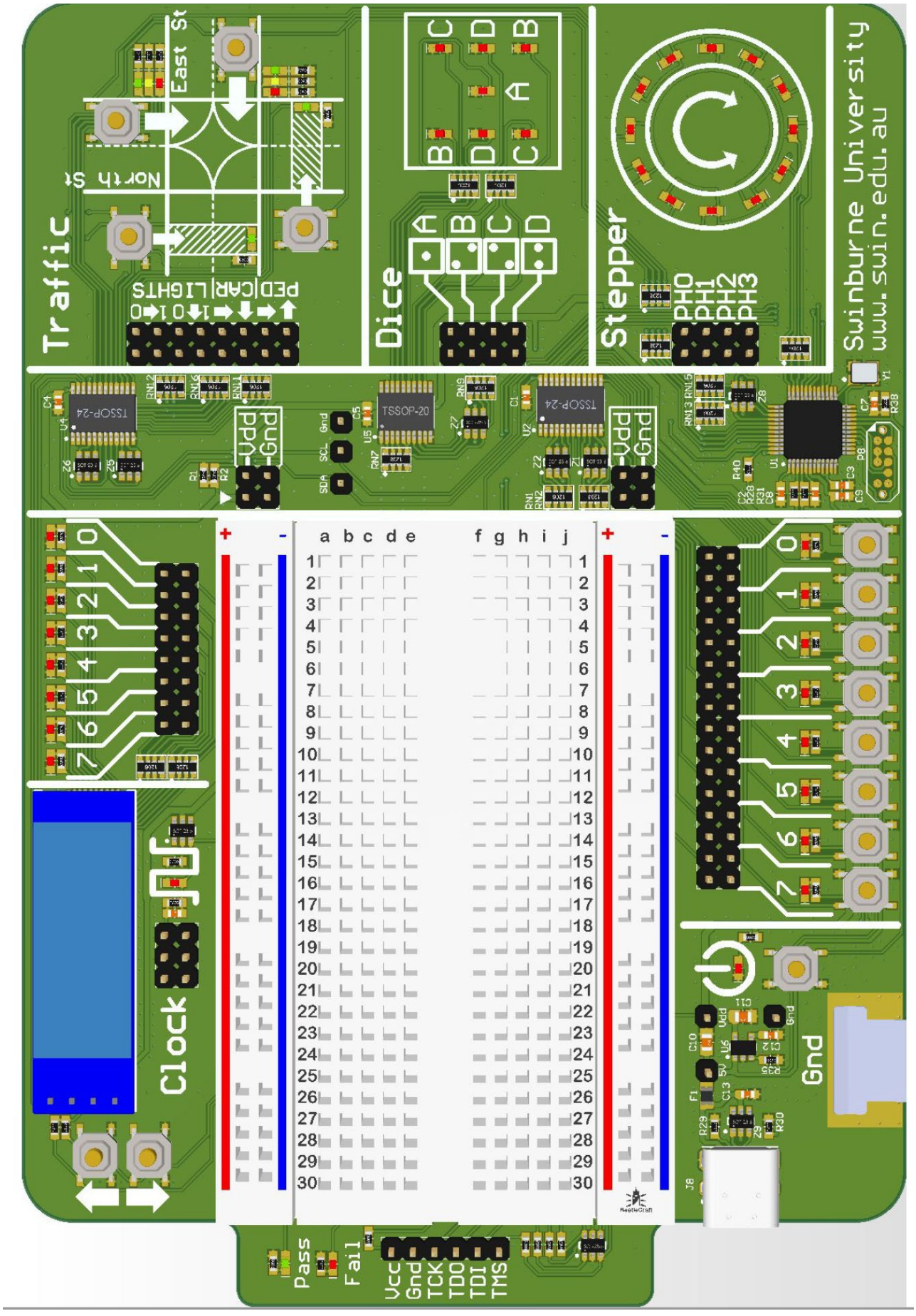
Negative lead indicated by stripe

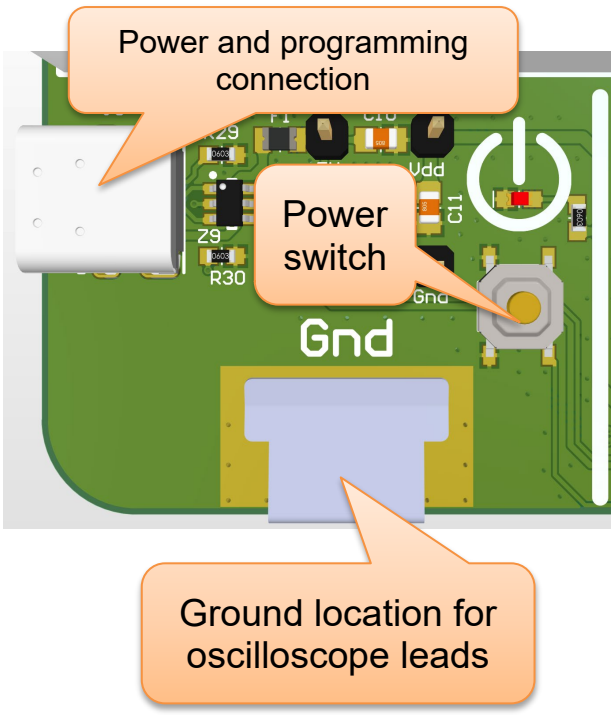


Resistors

Digital Logic Board

Details of this design are available at: https://github.com/podonoghue/DigitalLabBoard





Power and Ground clip location

The power for the board is obtained through a USB-C connector. A suitable USB lead with right-angle connector is provided.

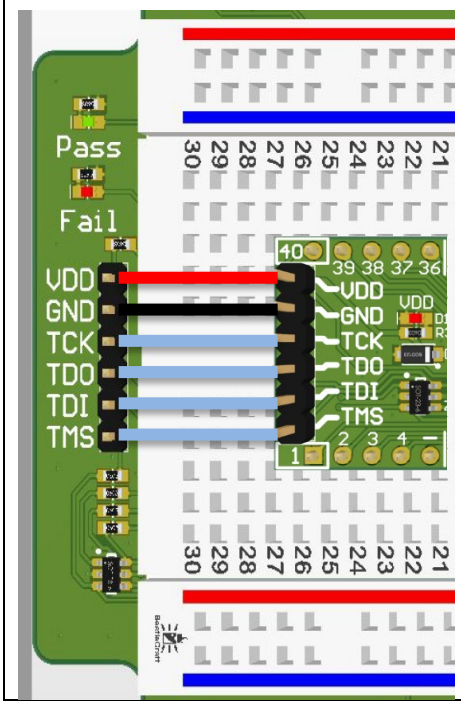
The on-board regulator reduces this to 3.3V to power the board.

There is soft power button that controls the power to the breadboard.
The power will also switch off if the supply is overloaded.

Any settings, such as latched buttons or clock frequency are preserved when the soft power button is used.

A metal clip provides a convenient location for the ground clip of oscilloscope leads.

The board should be soft powered-off when making wiring changes or moving the programming cable.



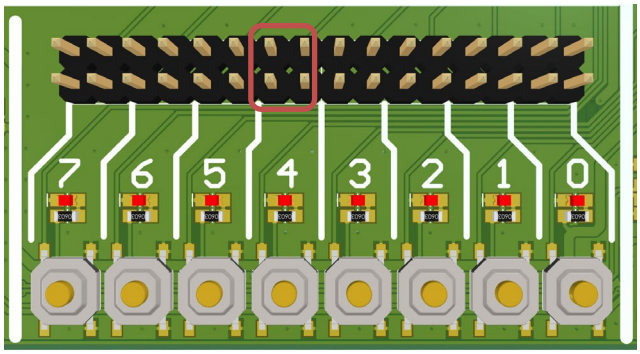
CPLD Programming interface (JTAG)

The programming interface allow the design to be downloaded to the CPLD from a PC via the USB interface.
The required software is available on Canvas.

The two LEDs indicate the outcome of the last programming action.
Pass => Successful
Fail => Failed – check the status in the programming software for more information. The most common error is likely to be a wiring mistake on the JTAG leads or the no power to the CPLD.

The Red LED will also flash during programming.

Switch Module



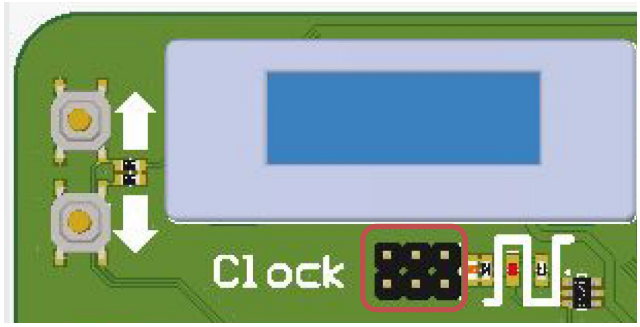
The outputs have 470 Ω series resistors for protection.

This provides 8 de-bounced switches that can be used as inputs to your circuit. Each output is connected to a group of four pins (2x2) as indicated for switch 4.

Switches are momentary action but will latch high if held for ~2 seconds. Press again to release.

The LED is on when the output is high.

Clock Module



The LED is on when the output is high.

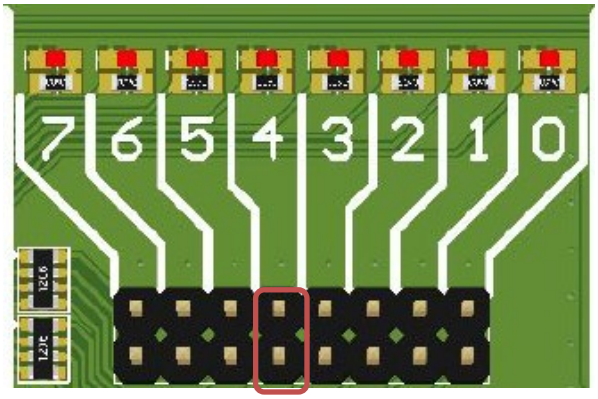
The output has a 100 Ω series resistor for protection.

This produces a square wave in the following frequencies:
1,2,5,10,20,50,100,200,500 Hz, and
1,2,5,10,20,50,100,200,500 kHz, and
1,2 MHz

The up/down button may be used to move between the available settings.

The clock output is connected to all six pins (2x3).

LED Module

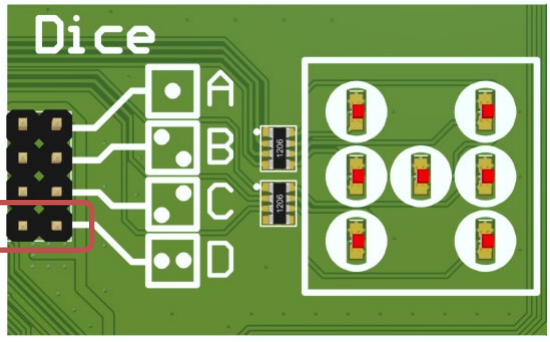


This allows 8 signals to be monitored on 8 LEDs. Each input is connected to a pair of pins (1x2) in the central block as indicated for LED 4.

The inputs are buffered so only lightly load the input signal.

The inputs have weak pull-down resistors (~10K).

Dice Module



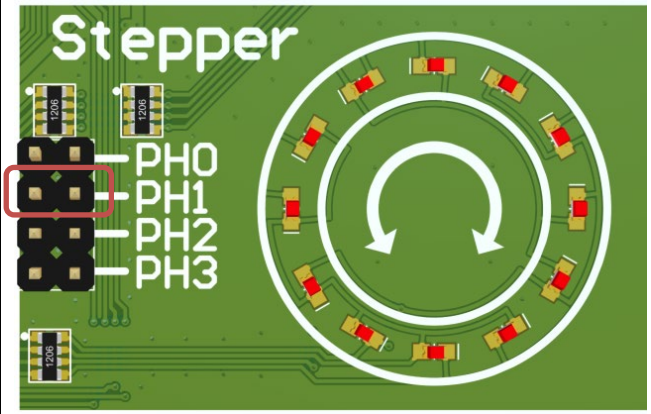
This provides 7 LEDs arranged in a dice pattern.

Each input is connected to a pair of pins (2x1) and controls one or more LEDs as shown in the legend e.g. the B input controls two diagonal LEDs.

The inputs are buffered so only lightly load the input signal.

The inputs have weak pull-down resistors (~10K).

Motor Module



Provides 12 LEDs arranged in a circle to represent the positions of a stepper motor.

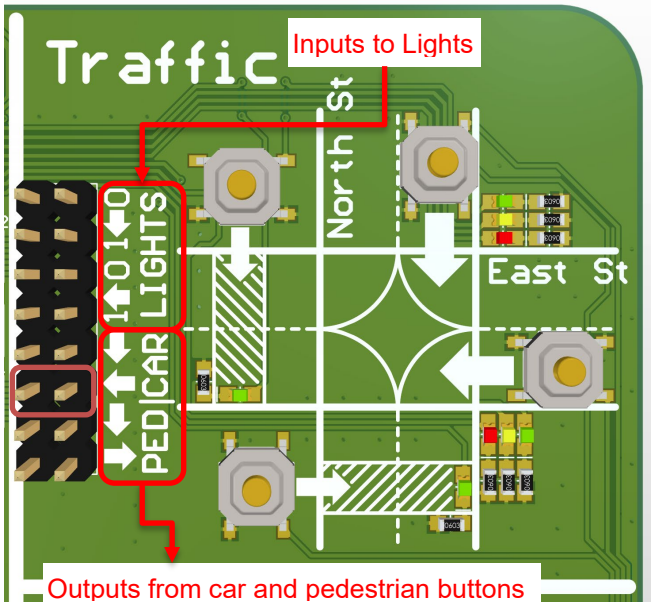
The 4 inputs to the board represent the 4 phases of the stepper motor coil drivers. The illuminated LED will move clockwise/anti-clockwise when the appropriate sequence is presented at these inputs.

Each input is connected to a pair of pins (2x1) in the central block

The LED inputs have weak pull-down resistors (~10K).

The inputs are buffered so only lightly load the input signal.

Traffic Intersection Module



Provides a simple simulation of a traffic intersection with the following elements:

Inputs to module (Traffic Lights + Walk light)

The lights have a 2-bit input to control a set of 4 lights (Red/Amber/Green Traffic + Green Walk)

- North-South lights
- East-West lights

Input 1 0	Lights ← ↓
0 0	Red
0 1	Amber
1 0	Green
1 1	Green + Walk

Outputs from module (Buttons)

Each car or pedestrian is represented by a de-bounced button with an individual output reflecting its value.

- Car travelling North to South (CAR↓)
- Car travelling East to West (CAR←)
- Pedestrian crossing North to South (PED↓)
- Pedestrian crossing West to East (PED→)

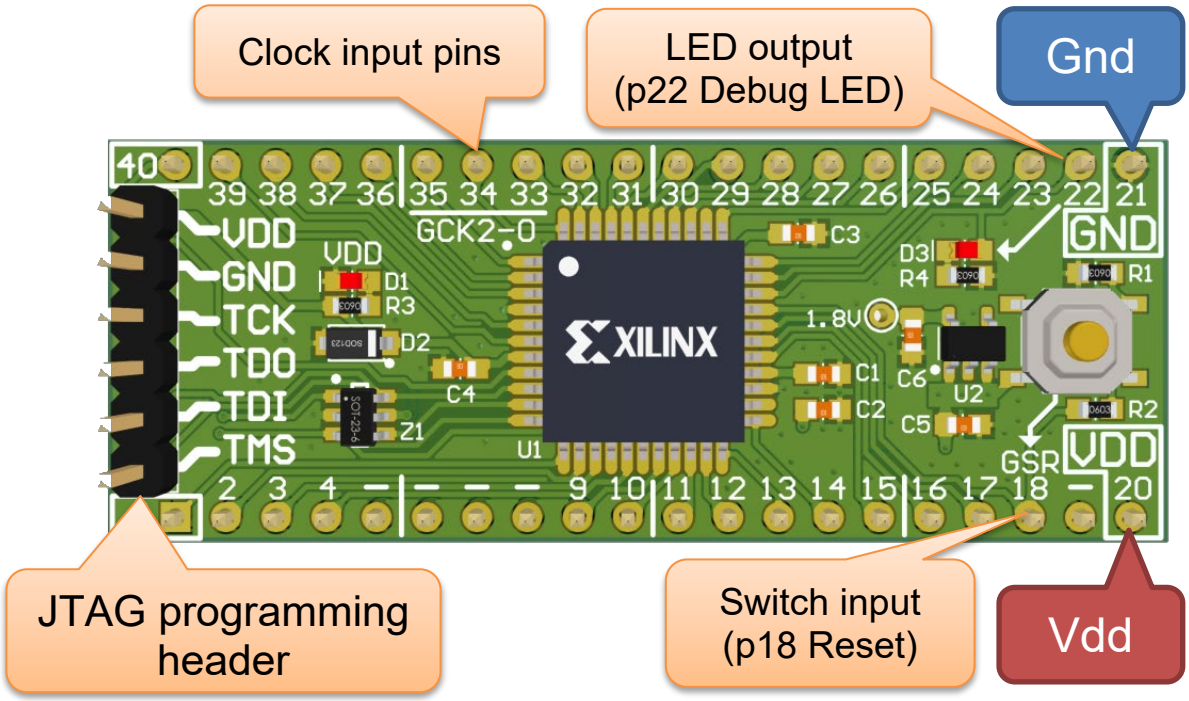
The inputs are buffered so only lightly load the input signal.

The inputs have weak pull-down resistors (~10K).

The outputs have 470 Ω series resistors for protection.

CPLD Module

Details of this design are available at: https://github.com/podonoghue/CPLD_Breakout

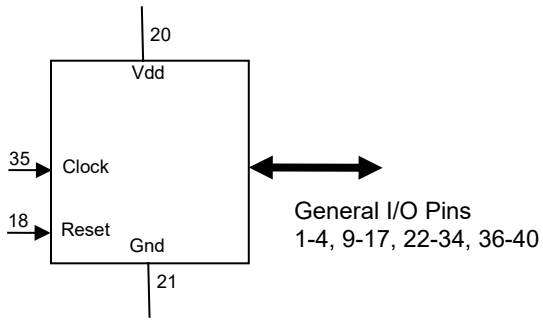


This module provides a convenient interface to a Xilinx XC2C64A CPLD. This device is large enough to implement all the functions constructed in the laboratory program but cheap enough that we don't cry too much when you blow them up 😢.

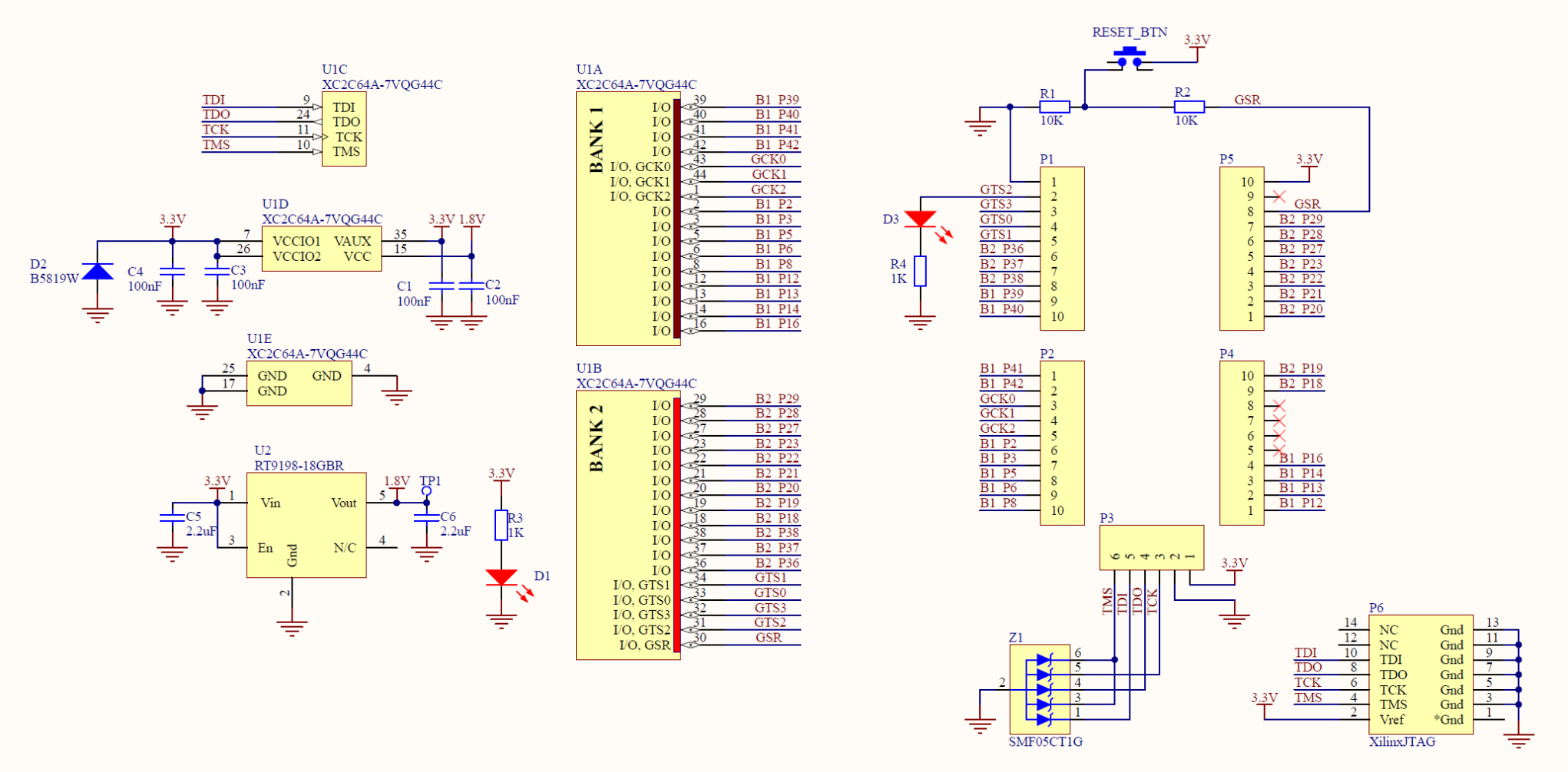
The inputs and outputs of the CPLD are NOT protected so it is important to check your wiring and be aware of static electricity. Do not alter the circuit while it is powered.

Most of the pins connect directly to the prototyping board and then allow connection to the I/O devices being used, for example the LEDs, switches and the clock board. Refer to the 'UCF' file (C-MOD.ucf) provided with the VHDL project material for actual CPLD pin numbers. Use of the UCF file is described in detail on Canvas.

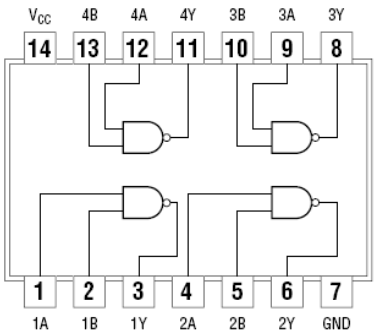
In addition, there is a row of pins used to connect to the CPLD programming interface. The desired hardware function would be designed using the Xilinx ISE software running on a PC and then downloaded to the device using this interface. This is a non-volatile device so once programmed with the desired functionality it will be retained even if power is disconnected.



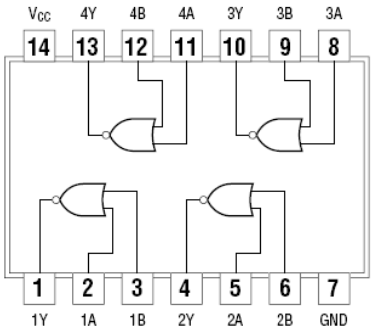
Simplified CPLD Module Schematic


U1C
XC2C64A-7VQG44C
TDI
TDO
TCK
TMS
U1D
XC2C64A-7VQG44C
VCCIO1
VCCIO2
VAUX
VCC
3.3V
1.8V
D2
B5819W
C4
100nF
C3
100nF
C1
100nF
C2
100nF
U1E
XC2C64A-7VQG44C
GND
U2
RT9198-18GBR
Vin
Vout
En
Gnd
N/C
C5
2.2uF
C6
2.2uF
TP1
R3
1K
D1
U1A
XC2C64A-7VQG44C
BANK 1
I/O, GCK0
I/O, GCK1
I/O, GCK2
GCK0
GCK1
GCK2
U1B
XC2C64A-7VQG44C
BANK 2
I/O, GTS1
I/O, GTS0
I/O, GTS3
I/O, GTS2
I/O, GSR
GTS1
GTS0
GTS3
GTS2
GSR
RESET_BTN
R1
10K
R2
10K
GSR
D3
R4
1K
P1
GTS2
GTS3
GTS0
GTS1
B2_P36
B2_P37
B2_P38
B1_P39
B1_P40
P5
GSR
B2_P29
B2_P28
B2_P27
B2_P23
B2_P22
B2_P21
B2_P20
P2
B1_P41
B1_P42
GCK0
GCK1
GCK2
B1_P2
B1_P3
B1_P5
B1_P6
B1_P8
P4
B2_P19
B2_P18
B1_P16
B1_P14
B1_P13
B1_P12
P3
TMS
TDI
TDO
TCK
Z1
SMF05CT1G
P6
NC
Gnd
TDI
TDO
TCK
TMS
Vref
*Gnd
XilinxJTAG

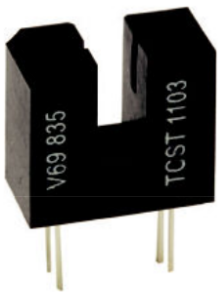
Integrated Circuit Pin-outs



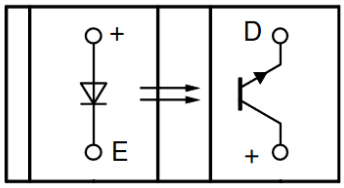
74HC00
Quad NAND gate



74HC02
Quad NOR gate



Top view



VISHAY TCST1103
Photo-interrupter

Detailed information about the various ICs is available on Canvas in the Laboratory area.