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# Digital I/O Board Kit (#27113)

The Parallax Digital I/O Board Kit enables your microcontroller to interface to high voltage circuits allowing you to read up to 8 optically isolated inputs and control up to 8 isolated outputs. Inputs can be a voltage from 5–30 VDC (AC compatible). Outputs can be either mechanical or solid state relays, and can switch up to 8 A loads, such as cooling fans, solenoids, heating elements and more.

Simple parallel input/output control for ease of use or you can use the serial interface to minimize I/O pin usage. The logic circuits operate from 3.3 V to 5 V making them compatible with most microcontrollers. The ICs in the kit are all socketed, making replacement easy should it ever be necessary. Eight green and eight red LEDs indicate the status of input and outputs. Two yellow LEDs indicate relay/logic power. Inputs can be configured to handle a different range of input voltages by changing a few components.

## Features

- Mechanical or solid state relay output
- Configurable input voltage range
- Serial or parallel interface to inputs/outputs
- LED indication of power and input/output status
- Compatible connector for the BASIC Stamp Board of Education AppMod header

## **Key Specifications**

- Power requirements: 12 VDC @ 1 A for relay power and 3.3–5 VDC for logic power
- Communication: parallel or synchronous serial
- Operating temperature: 32 to +158 °F (0 to +70 °C)
- Dimensions: 7.25" L x 4.50" W x 1.00" H (184.1 mm x 114.3 mm x 25.4 mm)

#### **Application Ideas**

- Isolated power control of high voltage/current devices from your microcontroller, such as heating elements, blower fans, solenoids, lighting systems and more
- Isolated monitoring of high voltage signals such as doorbell, alarm or other signals.

#### **Product Notices**

- Relays are not included with this kit and must be purchased separately. Mechanical Relays are part #400-00052 and Solid State Relays are part #400-00053.
- This product comes as a kit and must be assembled by the customer. Soldering experience is required to assemble this kit and the following tools are required: safety glasses, soldering iron, solder, flux (optional), diagonal cutters (to remove extra leads), needle-nosed pliers (optional, to bend/form leads)
- CAUTION: This product is capable of switching high voltages. Observe the safety precautions listed in this documentation.
- CAUTION: Although the Omron mechanical relays can switch up to 12 A, the Digital I/O Board can only switch 8 A safely. Do not exceed this limitation when controlling high power devices.

#### **Bill of Materials**

| Part #    | Part # Designator Description |   | Quantity |
|-----------|-------------------------------|---|----------|
| 200-01040 | C1-C3                         | Capacitor, .1uF Monolithic, 100V, 10%         | 3        |
| 201-01075 | C4                            | Capacitor, 1000uF, Electrolytic, 25V, 20%     | 1        |
| 350-00006 | D1-D8                         | LED, Red T1-3/4                               | 8        |
| 350-00007 | D26, D28                      | LED, Yellow T1-3/4                            | 2        |
| 350-00001 | D9-D16                        | LED, Green T1-3/4                             | 8        |
| 501-00006 | D17-D24                       | Diode, 1N4004 Rectifier                       | 8        |
| 501-00007 | D25                           | Diode, Schottky, 40V/3A                       | 1        |
| 179-00050 | RN1                           | Resistor Network, 8-ISO, 1K, 1/4W, 2%, DIP-16 | 1        |
| 150-01020 | R1-R8,R33,R42                 | Resistor, 1K, 1/4W, 5%                        | 10       |
| 156-02235 | R1_B-R8_B                     | Resistor, 560, 1/4W, 5%                       | 8        |
| 150-02210 | R9-R16,R34                    | Resistor, 220, 1/4W, 5%                       | 9        |
| 150-01030 | R17-R24,R43                   | Resistor, 10K, 1/4W, 5%                       | 9        |
| 156-02240 | R25-R32                       | Resistor, 1.5K, 1/4W, 5%                      | 8        |
| 602-01040 | U1-U8                         | IC, 4N25 Optoisolator, DIP-6                  | 8        |
| 500-00005 | U9                            | IC, ULN2803 Darlington Array, DIP-18          | 1        |
| 602-00009 | U10                           | IC, 74HC595 Shift Register, DIP-16            | 1        |
| 602-00010 | U11                           | IC, 74HC165 Shift Register, DIP-16            | 1        |
| 452-00052 | S1-S8                         | Socket, IC, DIP-16                            | 8        |
| 452-00053 | S9                            | Socket, IC, DIP-18                            | 1        |
| 452-00054 | S10-S11                       | Socket, IC, DIP-16                            | 2        |
| 452-00012 | J1-J17                        | 2-Position Terminal Block                     | 21       |
| 452-00007 | J18                           | 2.1mm DC Barrel Jack                          | 1        |
| 452-00049 | J19                           | 2x10 (20-pin) Dual Row Header                 | 1        |
| 452-00048 | J20                           | 2x5 (10-pin) Dual Row Header                  |          |
| 451-00301 | JP1                           | 3-pin SIP Header                              |          |
| 451-00201 | JP2                           | 2-pin SIP Header 1                            |          |
| 452-00009 | —                             | Shorting Block (Shunt)                        | 1        |
| 300-27113 | PCB1                          | Raw PCB                                       | 1        |

#### **Resources and Downloads**

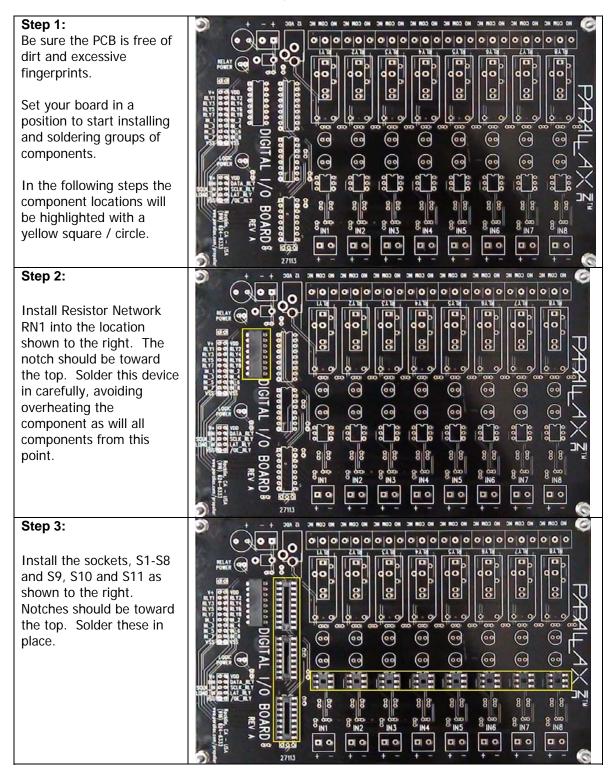
You may download free example programs, articles, videos etc. from the Digital I/O Board product page on our website. Check back periodically for updates or additional examples including example programs, customer applications, articles, etc.

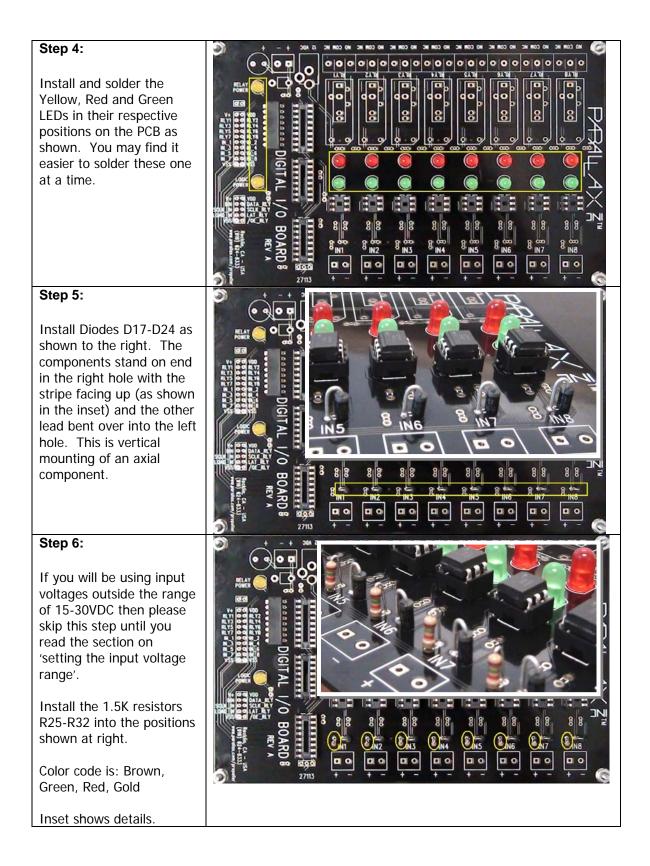
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# Assembly Instructions

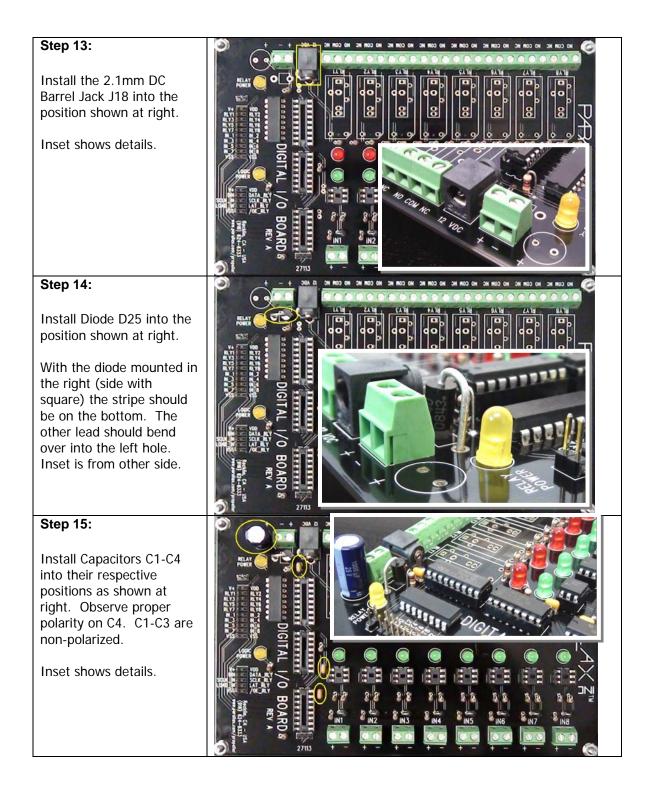
Before starting assembly, be sure you have the necessary tools and a clean area to work in. We'll start with the lower profile components and work our way up to taller components.

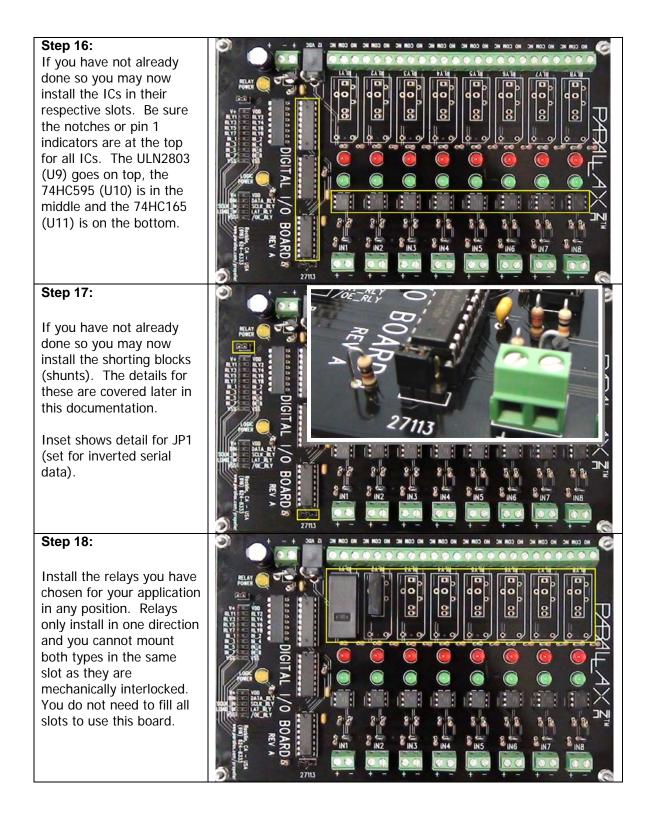




| Step 7:   |  |
|---|--|
| Install the 220 ohm<br>resistors R9-R16 and R34<br>into the positions shown at<br>right.<br>Color code is: Red, Red,<br>Brown, Gold<br>Inset shows details.           |  |
| Step 8:<br>Install the 10K resistors<br>R17-R24 and R43 into the<br>positions shown at right.<br>Color code is: Brown,<br>Black, Orange, Gold<br>Inset shows details. |  |
| Step 9:<br>Install the 1K resistors R1-<br>R8, R33 and R42 into the<br>positions shown at right.<br>Color code is: Brown,<br>Black, Red, Gold<br>Inset shows details. |  |

| Step 10:   |  |
|--|--|
| Install the 560 ohm<br>resistors R1_B-R8_B into<br>the positions shown at<br>right.<br>Color code is: Green, Blue,<br>Brown, Gold<br>Install these in the same<br>manner as previous<br>resistors.   |  |
| Step 11:<br>Install the headers<br>resistors J19, J20, JP1 and<br>JP2 into the positions<br>shown at right.<br>Inset shows details.  |  |
| Step 12:<br>Install the Terminal Blocks<br>J1-J17 (21 pcs total) into<br>the positions shown at<br>right.<br>Note: 12 Terminal Blocks<br>must be snapped together<br>for the relay connections.<br>These slide together<br>vertically to create one<br>long strip. |  |





## **Relay Selection (Mechinical or SSR)**

The Digital I/O Board is capable of using Omron Mechanical Relays (#400-00052) or Sharp Solid State Relays (#400-00053). You can use either relay in any of the eight available relay slots in any combination. The slots are mechanically interlocked to prevent you from using both types in the same position. The Mechanical Relays can switch up to 250 VAC @ 12 A (24 VDC), however do not exceed 8 A on this board. The Solid State Relays can switch up to 240 VAC @ 8 A (AC ONLY). Unlike the mechanical relays, solid state relays do not exhibit contact noise or arcing. These Sharp Relays even provide zero-crossing detection to reduce switching noise, however they can only switch AC voltage, not DC.

#### **Relay Power**

No matter which relays you use the Digital I/O Board requires a separate 12 V @ 1 A power supply for the relays. This power is provided through 2.1 mm Barrel Jack at the top left of the board or optionally via the 2-position terminal block next to it. The terminal block is labeled + and – which the DC barrel jack is center tip positive, making it compatible with our power supplies (Parallax recommends #750-00007). Minimal reverse polarity protection is provided by diode D25.

#### Logic Power

The control logic requires power from the host microcontroller for the inputs to function. This will be either 3.3 V or 5 V from your microcontroller provided to the VDD pin on the Digital I/O Board. Your microcontroller's ground should connect to the VSS pin. This allows the Digital I/O Board to operate at a signal level compatible with your microcontroller. The V+ pin allows your microcontroller to get supply voltage from the Digital I/O Board (reducing the need for an additional power supply). If your microcontroller's board has an on-board voltage regulator, you can obtain V+ from the Digital I/O Board and then send your regulated output back to the VDD pin. V+ will be at the voltage of the relay supply (typically ~12VDC).

#### **Connecting and Testing (Parallel Interface)**

Using the parallel interface (2x10 header) controlling relays is as simple as making a pin HIGH or LOW. To energize a particular relay make its control pin HIGH. To turn it off bring that pin LOW. If your microcontroller's output pins are set to input the relays will also turn off due to internal pull-down resistors within the ULN2803 IC. Inputs are easily read by reading a HIGH or LOW on their output pins (labeled IN\_1 through IN\_8). Note that because the optocoupler inverts the signal, the pins will read HIGH when that input is inactive and will read LOW when that input is active.

Note: Do not use the parallel and serial circuits at the same time. Use only one type of interface.

#### Connecting to an AppMod Header

The parallel interface (2x10 header) was designed to be compatible with the AppMod header on our popular BASIC Stamp Board of Education development board. You could use a ribbon cable (not included) to connect both boards together instantly connecting all necessary power and ground for a fully functioning parallel control system.

When using the AppMod interface there are two additional considerations. You should use the I/O declarations in the example code for the AppMod because the I/O pins are now mapped to specific pins on the Digital I/O Board and these may not be what you expect. Also, the V+ connection allows the Board of Education to get power from the Digital I/O Board. If you do not want this to happen you must remove the 2-pin shunt from JP2 above the parallel interface. This disables the V+ pin on that header, but still allows the Board of Education to provide 5V to VDD on the Digital I/O Board.

## **Connecting and Testing (Serial Interface)**

The serial interface (2x5 header) allows you to reduce the number of pins required to control the Digital I/O Board by serially shifting data to/from the board over a synchronous serial interface. Whereas full control requires 16 I/O pins using the parallel interface, the serial interface can provide full control with as few as 4 I/O pins.

The pins labeled DATA RLY, SCLK RLY, LAT RLY and /OE RLY are connected to a 74HC595 serial to parallel shift register. These pins have the following functions: DATA\_RLY is serial data going out to the shift register. This data is sent MSB first (8 bits) synchronously with the SCLK\_RLY pin. On the BASIC Stamp this can be achieved with the SHIFTOUT command. Once the data has been shifted out the LAT\_RLY pin must be pulsed to latch the data onto the outputs. /OE\_RLY must be LOW in order for the 74HC595 to drive the relays. This can be tied to VSS or controlled via an I/O pin.

The pins labeled DIN, SCLK\_IN and LOAD\_IN are connected to a 74HC165 parallel to serial shift register. These pins have the following functions: DIN is serial data from the shift register sent synchronously with a clock pulse on SCLK\_IN generated by the host microcontroller. On the BASIC Stamp this is achieved with the SHIFTIN command. Before data is shifted in the current contents of the inputs must be loaded. This is accomplished by pulsing the LOAD\_IN line from HIGH to LOW and then back to HIGH. This line must remain HIGH during shift operations and must only go LOW during a LOAD operation.

The DIN line has a 1K resistor in series to allow sharing of the 74HC165 data line with the 74HC595 DATA\_RLY line. By connecting these lines together and also connecting SCLK\_RLY to SCLK\_IN you can reduce the number of I/O pins required by your microcontroller down to four (4). In this configuration LAT\_RLY and LOAD\_IN must have their own I/O pins and /OE\_RLY can be connected to VSS. This circuit provides a half-duplex system where you can access one shift register at a time. For full duplex operation the DIN and DATA\_RLY lines must be separate and for independent operation the SCLK\_RLY and SCLK\_IN must also be separate.

Note: Do not use the parallel and serial circuits at the same time. Use only one type of interface.

#### **Communication Protocol**

The serial protocol (synchronous serial) used by the 74HC595 and 74HC165 is defined in more detail in the datasheets for each device. BASIC Stamp users can also download the free PDF and example code for the Stamp Works kit and review experiments 23 through 25 which deal with these shift registers both independently and together.

# Mode Jumper (JP1)

The 3-pin jumper just below the 74HC165 determines whether the data shifted in from the shift register is inverted or not. Because the optocouplers inherently invert the data, when reading inactive inputs you get all ones instead zeros which isn't very intuitive. This jumper allows you to invert the data to normalize the output and make it more intuitive. In the 1-2 position data is inverted and when an input is active is will make its output go HIGH. With JP1 in the 2-3 position data is not inverted and when an input is active you will get a LOW.

Note: The Parallel interface is unaffected by this jumper. Therefore the parallel signals from the 74HC165 are always inverted

## Setting Input Voltage Range

This kit comes with 1.5K resistors on the inputs (R25-R32). These resistors were chosen as the defaults based on a typical input voltage range of 15-30 VDC (24 nominal). If you wish to input a different range of voltages you will need a different resistor value in place of the default 1.5K unit. To calculate this value it is necessary to have a few key pieces of information. First and foremost the Digital I/O Board is configured to require a minimum of 8mA of current across an optocoupler LED for the output transistor to trigger an output. Ideally you'll probably set the current range for your input voltage to 10-20 mA.

Given this range of current we can calculate the required resistor using the following math:

 $R = (V_{IN} - V_{EWD}) / I_{LED}$  (where  $V_{EWD}$  is the LED forward voltage, ILED is LED current and  $V_{IN}$  is our input voltage)

Assuming we want be able to input a 12V signal and accounting for the typical forward voltage for the 4N25 of 1.2V we can now calculate as follows:

R = (12V - 1.2V) / 0.01 = 1080

The closest value is 1K which will mean a current of 10.8mA @ 12V using I =  $(V_{IN} - V_{FWD}) / 1000$ 

We can also calculate the maximum voltage we want on the input using a 1K resistor:

 $V_{INMAX} = (1000 * 0.02) + 1.2 = 21.2V$ 

#### **Sensitivity**

Because of the way the input LEDs are driven on the output, they will indicate voltage on an input even when it is not sufficient to trigger and output. Voltage as low as 2 V will cause the LED to start to glow, however the output won't trigger until the minimum current has been reached. This provides some safety in the sense that you'll have an indication of input voltage in spite of the outputs not being triggered.

#### Precautions

As with any device capable of switching high voltages, precautions should always be taken to avoid damage and/or injury. The following precautions are recommended in addition to any precautions by the manufacturer of any equipment connected to this device.

- The Digital I/O Board should be mounted inside a suitable enclosure or electrical panel using standoffs. The board should not be able to move.
- Any electrical connections to the board should be secured so they can not move and any wires extending outside the enclosure should have strain relief.
- Any incoming voltage rails to be switched by the relays should be fused prior to entering the Digital I/O Board.
- Always be sure any incoming voltage rails are powered off prior to connecting them to the Digital I/O Board.
- When connecting the V+ pin to VIN on another board, be sure that board does not have its own power supply. The target board will now get power from the Digital I/O Board.

# **Specifications**

| Symbol            | Quantity                             | Minimum | Typical | Maximum | Units |
|-------------------|--------------------------------------|---------|---------|---------|-------|
| V+                | Relay Supply Voltage                 | 9       | 12      | 15      | V     |
| VDD               | Logic Supply Voltage                 | 3.3     | _       | 5       | V     |
| I <sub>LED</sub>  | Input LED Forward Current            | 8       | 10      | 20      | mA    |
| I <sub>IDLE</sub> | Idle Current (Relay Power Only, Off) | —       | 10.5    | —       | mA    |
| —                 | Maximum Current Capability of PCB    | —       | _       | 8       | А     |

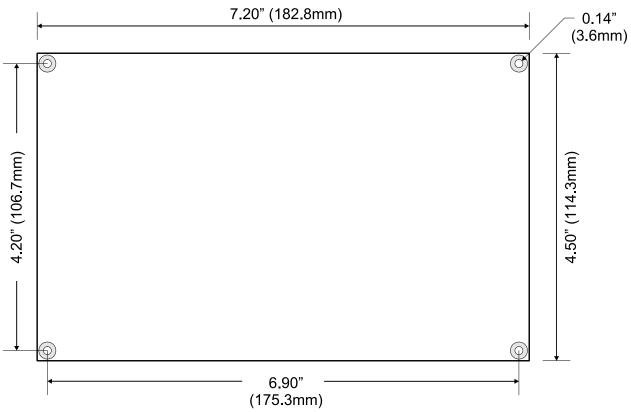
# Pin Definitions for 2x10 Header (Matches AppMod connector)

| Pin | Name | Function                                  |
|-----|------|---|
| 1   | V+   | Relay Power (Can be disconnected via JP2) |
| 2   | VDD  | Logic Power                               |
| 3   | RLY1 | Relay 1 Control Line                      |
| 4   | RLY2 | Relay 2 Control Line                      |
| 5   | RLY3 | Relay 3 Control Line                      |
| 6   | RLY4 | Relay 4 Control Line                      |
| 7   | RLY5 | Relay 5 Control Line                      |
| 8   | RLY6 | Relay 6 Control Line                      |
| 9   | RLY7 | Relay 7 Control Line                      |
| 10  | RLY8 | Relay 8 Control Line                      |
| 11  | IN_1 | Input 1 Signal                            |
| 12  | IN_2 | Input 2 Signal                            |
| 13  | IN_3 | Input 3 Signal                            |
| 14  | IN_4 | Input 4 Signal                            |
| 15  | IN_5 | Input 5 Signal                            |
| 16  | IN_6 | Input 6 Signal                            |
| 17  | IN_7 | Input 7 Signal                            |
| 18  | IN_8 | Input 8 Signal                            |
| 19  | VSS  | Ground                                    |
| 20  | VSS  | Ground                                    |

| Pin | Name     | Function   |
|-----|----------|--|
| 1   | V+       | Relay Power (output to host controller)                      |
| 2   | VDD      | Logic Power (input from host controller)                     |
| 3   | DIN      | Serial Data In from 74HC165 (output to host controller)      |
| 4   | DATA_RLY | Serial Data Out to 74HC595 (input from host microcontroller) |
| 5   | SCLK_IN  | Synchronous Serial Clock (input from host microcontroller)   |
| 6   | SCLK_RLY | Synchronous Serial Clock (input from host microcontroller)   |
| 7   | LOAD_IN  | Load Inputs (input from host microcontroller)                |
| 8   | LAT_RLY  | Latch Relay Output (input from host microcontroller)         |
| 9   | VSS      | Ground   |
| 10  | /OE_RLY  | Relay Output Enable (input from host microcontroller)        |

#### Pin Definitions for 2x5 Header

## **Module Dimensions**



#### **Module Schematic**

A full size schematic in PDF format is available from the product page on our website.

# **Revision History**

Version 1.1: Description and Product Notices caution added stating that board's current limit is 8 A.