Power I/O Wildcard User Guide

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The Power I/O Wildcard provides eight high-current isolated MOSFET outputs and four high voltage isolated inputs. This tiny 2" by 2.5" module is a member of the Wildcard™ series that connects to the QED Board or PanelTouch Controller host via the Wildcard Carrier Board, or connects directly to the EtherSmart™ Controller.

This document describes the capabilities of the Power I/O Wildcard, tells how to use and configure the hardware, shows how to read the inputs and write to the outputs, and presents the complete hardware schematics.

Power I/O Wildcard Hardware

The Power I/O Wildcard provides eight opto-isolated current-sinking outputs, and four opto-isolated high-voltage inputs. Jumpers enable module address selection and optional pull-up of the inputs. A Wildcard bus header connects to the host processor (QED Board, Panel-Touch Controller, or EtherSmart Controller), and a field header brings out the isolated I/O signals. Table 1-1 provides specifications for the module's inputs and outputs.

Table 1-1 Power I/O Wildcard Specifications

High Current DC Outputs (each channel, without heat sink, T_A = 0 to 70°C)	
Output Channels	8 isolated current sinking outputs with common field supply and ground
Isolation	Optically isolated to ± 2500 V, 10^{11} Ω isolation resistance
Output Protection	Snub diodes to field supply to protect against inductive spikes
Field Voltage	+1 to +50 VDC max
OFF Voltage	+1 to +50 V (field supply)
OFF Leakage	< 25 µA at 25° C
ON Voltage	0.6 V typical at 2 A continuously 0.3 V typical at 2 A intermittently
Max ON Resistance	<0.2 Ω at I < 1A, typically 0.15 Ω <0.3 Ω to <0.4 Ω (at I = 2A for T_A = 25 to 70°C)
Max ON Current	2 A continuously; or, 2 A pulses from 25 V at 50% duty cycle at frequencies to 5 kHz; or, 10 A pulse (<50 msec on time, <6% duty cycle at T_A = 25°C or <4% duty cycle at T_A = 70°C).
Switching Times	t_{on} = 9 µsec, t_{off} = 12 µsec for 10%-90% transitions

Voltage / Switch Inputs (each channel)	
Input Channels	4 isolated bipolar voltage or switch closure inputs, with a common field ground and optional pull-ups to a common field supply
Input High Voltage	± 4 to ±50 VDC
Input Low Voltage	< ± 0.8 V
Switch Inputs	Optionally pulled-up through 10kΩ to field supply
Isolation	Optically isolated to ± 2500 V, 10^{11} Ω isolation resistance

Connecting To the Wildcard Carrier Board

To connect the Power I/O Wildcard to the Wildcard Carrier Board, follow these simple steps:

1. Connect the Wildcard Carrier Board (also known as the "Module Carrier Board") to the QED Board as outlined in the "Wildcard Carrier Board User Guide".
2. With the power off, connect the 24-pin Module Bus on the Power I/O Wildcard to Module Port 0 or Module Port 1 on the Wildcard Carrier Board. The corner mounting holes on the module should line up with the standoffs on the Wildcard Carrier Board. The module ports are labeled on the silkscreen of the Wildcard Carrier Board. Note that the Power I/O Wildcard headers are configured to allow direct stacking onto the Wildcard Carrier Board, even if other modules are also installed. Moreover, the latest version of the Wildcard Carrier Board is designed to directly stack onto the QED Board. Do not use ribbon cables to connect the Power I/O Wildcard to the Wildcard Carrier Board. Use of ribbon cables on the Power I/O Wildcard's field header is fine.

   CAUTION: The Wildcard Carrier Board does not have keyed connectors. Be sure to insert the module so that all pins are connected. The Wildcard Carrier Board and the Power I/O Wildcard can be permanently damaged if the connection is done incorrectly.

Selecting the Module Address

Once you have connected the Power I/O Wildcard to the Wildcard Carrier Board, you must set the address of the module using jumper shunts across J1 and J2.

The Module Select Jumpers, labeled J1 and J2, select a 2-bit code that sets a unique address on the module port of the Wildcard Carrier Board. Each module port on the Wildcard Carrier Board accommodates up to 4 modules. Module Port 0 provides access to modules 0-3 while Module Port 1 provides access to modules 4-7. Two modules on the same port cannot have the same address (jumper settings). Table 1-2 shows the possible jumper settings and the corresponding addresses.

Table 1-2 Jumper Settings and Associated Addresses

Module Port	Module Address	Installed Jumper Shunts
0	0	None
	1	J1
	2	J2
	3	J1 and J2
1	4	None
	5	J1
	6	J2
	7	J1 and J2

Outputs

The high current MOSFET outputs are opto-isolated to 2500 volts and capable of sinking 2 amps per channel continuously using field voltages up to 50 VDC at ambient temperatures to 70°C. The outputs are protected by snub diodes connected to the field supply to prevent damage from high-voltage inductive spikes. The MOSFET outputs control DC loads only. To control AC loads, use the AC Relay Wildcard, also available from Mosaic Industries.

Figure 1-1 shows how to connect a DC load (motor, solenoid, etc.) to the high current outputs. The field voltage supply (V+FieldOUT) can be as great as 50 VDC.

If you test the MOSFET outputs, remember to connect a load to the output in order to see a voltage change as the output changes state. To perform simple non-isolated testing to verify the functionality of the board, connect a resistor (say, 1 kΩ) between the output and any convenient field supply (such as +5V) and connect the output's field ground to the Ground connection of the +5V supply. Then, when an output bit is off, no current will flow in the load resistor, and a voltmeter or scope will show that its voltage is high (at +5V if you used this as the field supply). If you use the software from the software section of this document to turn an output bit on, current will flow through the output resistor, and your voltmeter or scope will show that the corresponding voltage falls to near zero.

The field connector on the Power I/O Wildcard is rated for continuous currents up to 2 amps and it should mate with a connector that is capable of carrying the required load current for your application. Note that standard insulation-displacement ribbon cable connectors are rated at only 1 amp per contact.

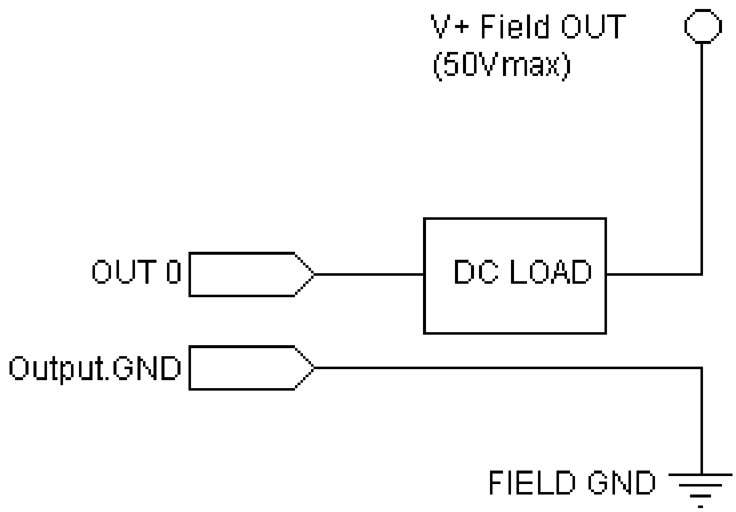


Figure 1-1 Connecting a DC load to a high current output.

Maximum Ratings: Current, Power and Switching Frequency

Without using heat sinks the outputs can each sink 2 A continuously. They can also sink pulses of greater current (up to 10 A) as long as the pulse duration and frequency do not cause a greater power dissipation than 2 A of continuous current does.

Owing to the low ON resistance of the MOSFETS the power dissipated in them is low: when OFF they are subjected to the field voltage but there is no current so no power is dissipated; when ON their internal resistance is low (typically 0.15 Ω) so the I^2R power is also low.

Without a heat sink, the maximum electrical power allowed for each channel is limited by convection/conduction from the MOSFET's TO-220 package, and depends on the ambient temperature, as shown in Equation 1-1. In the equation, T_{jmax} is the maximum junction temperature (175°C), T_A is the ambient temperature (0-70°C), and R_Θ is the junction to ambient thermal resistance (62 °C/W). For an ambient temperature increasing from 25°C to 70°C, the maximum power that can be dissipated decreases from 2.4 W to 1.7 W.

$$\text{Max Power Dissipated} = (T_{jmax} - T_A)/R_\Theta \qquad \text{Eqn. 1-1}$$

The heat generated in the MOSFET comprises two terms, an I^2R term and a frequency-dependent switching loss term, as given in Equation 1-2.

$$\text{Power Generated} = I^2 r_{ds} D + F\ I\ V\ (t_{on} + t_{off})/(6 \text{ or } 2) \qquad \text{Eqn. 1-2}$$

The first term is the product of the square of the ON current, the device resistance (r_{ds} = 0.4 Ω max at the max junction temperature), and the duty factor ($0<D<1$). The duty factor is the ratio of ON time to (ON + OFF) time if the channel is switched repeatedly. The duty factor is unity, (D=1), for continuous current. The second term represents switching loss incurred during the turn on and off transitions. It is the product of the frequency, F, the ON current and OFF voltage, I and V, and the sum of the ON and OFF transition times (21 µsec). There is either a 6 or a 2 in the denominator if switching resistive (use 6) or inductive (use 2) loads respectively. A load is considered inductive if its inductance , L, is greater than a threshold given by L > V t_{off} /4I. For example, if I=2A and V=25V, the load is inductive if its inductance is greater than 25V * 12µsec / (4 * 2A) = 38 µH.

The conditions of maximum current, voltage and frequency are found by setting the maximum package dissipation equal to the electrical power as shown in Equation 1-3.

$$(T_{jmax}-T_A)/R_\Theta = I^2 r_{ds} D + F I V (t_{on} + t_{off})/(6 \text{ or } 2) \qquad \textbf{Eqn. 1-3}$$

And substituting the appropriate constants, as,

$$(175-T_A)/62 = 0.4 I^2 D + 0.021 F I V / (6 \text{ or } 2) \qquad \textbf{Eqn. 1-4}$$

in which I is in amps, V in volts, D is a fraction between 0 and 1, F is in kHz, and T_A is in °C.

Equation 1-4 can be solved to find any of the parameters (I, V, D, F, T_A) given the others.

Example 1, finding maximum DC current: For continuous DC current (F=0 and the channel is ON so D=1) and a maximum ambient temperature of T_A=50°C, the maximum continuous current is found by solving Eqn. 1-4 to be 2.2 A. At the maximum specified ambient temperature, T_A=70°C, the maximum current is found to be 2.06 A.

Example 2, finding a maximum switching frequency: For driving a 1 A resistive load (I=1) from a field supply of 25 volts (V=25) with a duty cycle of 50% (D=0.5) at a maximum ambient temperature of T_A=70°C, we find a maximum frequency, F, of 17 kHz.

Example 3, finding a maximum switching frequency for an inductive load: For driving 1A into an inductive load (I=1) of 1 millihenry from a field supply of 25 volts (V=25) with a duty cycle of 50% (D=0.5) at a maximum ambient temperature of T_A=70°C, we use the denominator of 2 in the above equation and find a maximum frequency, F, of 5.6 kHz.

Example 4, finding duty cycle: PWM modulation of a thermoelectric cooler requires driving 4 A into the cooler at its minimum recommended frequency of 1 kHz from a 12 volt supply. The instrument must operate at ambient temperatures up to 70°C. That is, I=4, F=1kHz, V=6, and T_A=70°C. The maximum duty cycle is found as 24%.

<u>It's wise to stay well within the computed maximums.</u> In addition to these considerations there are transient effects for high current pulses. Pulses of 10 A must be restricted to times

less than 50 milliseconds, while 4 A pulses may have a maximum duration of 1 sec. Consult the IRLZ14 data sheet for details.

Heat Sinking

While it is possible to heat sink the MOSFETS, because of the limited space between MOSFETs and the need to electrically insulate the heat sink from each MOSFET we do not recommend heat sinking. Even so, if you are careful and you do heat sink the MOSFET drivers the maximum ratings improve. In particular, one or two of the channels can be heat sunk with small free-standing TO-220 heat sinks. To determine the maximum ratings, the same equation may be used, but with the appropriate thermal resistance substituted for R_{Θ}. To the heat sink thermal resistance (heat sink to ambient) you must always add the thermal resistance between the junction and the package of 3.5 °C/W, and the case to sink resistance, typically between 0.1 and 1.0 °C/W.

Small, free-standing heat sinks (0.5 x 0.5 x 0.75" heatsinks of 18.8 °C/W such as Digikey HS121-ND) can be used to decrease the thermal resistance from 62 to about 18.8+3.5+1.0 = 23.3 °C/W resulting in an increase in continuous current from 2A to 3.3A. The tabs of the TO-220 packages of the MOSFETs are not electrically isolated – they are connected to the drains (the outputs). Consequently, if the package is heat sunk the heat sink must be kept electrically insulated from the tabs, or it must be kept insulated from everything else.

Inputs

The high voltage inputs are also optically isolated to ±2500 volts and capable of sensing voltages of ±5 to ±50 VDC. Figure 1-2 illustrates how to connect an input voltage to the Power I/O Wildcard. When the input voltage is ±5-±50V, a logical 1 input will be read. When the input voltage is less than ±0.8V, a logical 0 input will be read.

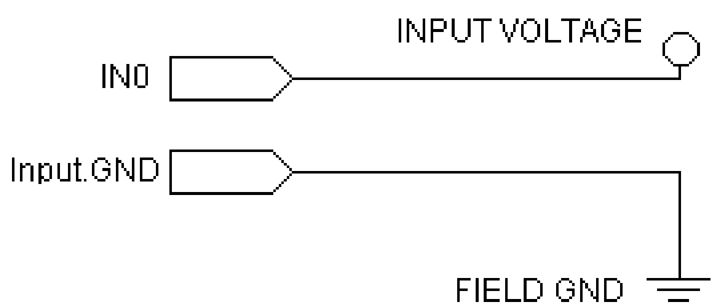


Figure 1-2 Connecting an voltage to a high voltage input.

Onboard pull-up resistors (labeled PU0 to PU3 on the Power I/O Wildcard silkscreen) allow you to monitor the state of a contact closure device such as a switch. The switch is connected as shown in Figure 1-3. For example, to interface a contact closure device to input channel IN1, install a jumper shunt across J5 and connect the contact closure device. The input is read as a logical 1 when the switch contact is open (contacts not connected), and it is read as a logical 0 when the device is closed (contacts connected). When the pull-up resistors are used, V+ Field IN must be in the range of ±5 to ±50VDC for proper operation.

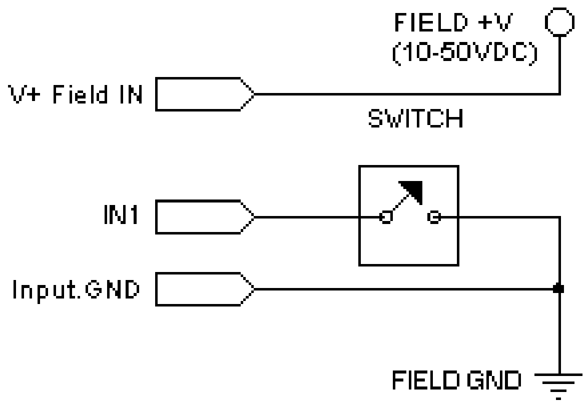


Figure 1-3 **Connecting a contact closure device such as a switch to the Power I/O Wildcard. To provide the proper voltage swing at the input, install a jumper shunt across J5. The input will be read as a logical 1 when the switch contact is open and as a logical 0 when the switch is closed.**

Power I/O Wildcard Field Header

The isolated high voltage inputs and outputs are brought out to a 24-pin dual row header on the Power I/O Wildcard as shown in Table 1-3.

To connect your transducer signals or control inputs to the Field Bus (H3 on the Power I/O Wildcard) use a ribbon cable or the Screw Terminal Module that brings out the signals to screw terminal blocks. Remember that most ribbon cable connectors are rated at 1 amp per contact.

Table 1-3 Power I/O Wildcard Field Header

Signal	Pins		Signal
0utput.GND	– 1	2 –	OUT7
0utput.GND	– 3	4 –	OUT6
0utput.GND	– 5	6 –	OUT5
0utput.GND	– 7	8 –	OUT4
0utput.GND	– 9	10 –	OUT3
0utput.GND	– 11	12 –	OUT2
0utput.GND	– 13	14 –	OUT1
0utput.GND	– 15	16 –	OUT0
V+FieldOUT	– 17	18 –	IN3
V+FieldIN	– 19	20 –	IN2
Input.GND	– 21	22 –	IN1
Input.GND	– 23	24 –	IN0

Software

To control the eight high current, isolated MOSFET outputs use the software primitives `StoreChar`, `ToggleBits`, `ChangeBits`, `SetBits`, or `ClearBits` (`C!`, `TOGGLE.BITS`, `CHANGE.BITS`, `SET.BITS`, or `CLEAR.BITS` in FORTH). To read back the state of the eight outputs or the four inputs, use the software primitive `FetchChar` (`C@` in FORTH). The hexadecimal address of the output port is 0xC000 and the address of the input port is 0xC001. The page corresponds to the module address. Code Listings 1-1 and 1-2 provide functions that set, clear, and read the high current isolated outputs, and a function that reads the high voltage isolated inputs.

Listing 1-1 C Code to control the Power I/O Module.

```
#include <allqed.h>

#define OUTPUT_REGISTER 0xC000
#define INPUT_REGISTER  0xC001

\\ module_num = the hardware jumper setting described in Table 1-2.
\\ valid module numbers are 0 tp 7.
\\ bit = a bit mask with 1's in the position of bits to be set.
void SetOutput( uchar bit, uchar module_num )
{
  EXTENDED_ADDR module_addr;
```

```
  module_addr.sixteen_bit.page16 = module_num;
  module_addr.sixteen_bit.addr16 = OUTPUT_REGISTER;
  SetBits(bit,module_addr.addr32);
}

\\ module_num = the hardware jumper setting described in Table 1-2.
\\ valid module numbers are 0 tp 7.
\\ bit = a bit mask with 1’s in the position of bits to be cleared.
void ClearOutput( uchar bit, uchar module_num )
{
  EXTENDED_ADDR module_addr;
  module_addr.sixteen_bit.page16 = module_num;
  module_addr.sixteen_bit.addr16 = OUTPUT_REGISTER;
  ClearBits(bit,module_addr.addr32);
}

\\ module_num = the hardware jumper setting described in Table 1-2.
\\ valid module numbers are 0 tp 7.
uchar ReadOutput( uchar module_num )
{
  EXTENDED_ADDR module_addr;
  uchar output_status;
  module_addr.sixteen_bit.page16 = module_num;
  module_addr.sixteen_bit.addr16 = OUTPUT_REGISTER;
  output_status = FetchChar( module_addr.addr32 );
  return( output_status );
}

\\ module_num = the hardware jumper setting described in Table 1-2.
\\ valid module numbers are 0 tp 7.
uchar ReadInput( uchar module_num )
{
  EXTENDED_ADDR module_addr;
  uchar input_status;
  module_addr.sixteen_bit.page16 = module_num;
  module_addr.sixteen_bit.addr16 = INPUT_REGISTER;
  input_status = FetchChar( module_addr.addr32 );
  return( input_status );
}
```

Listing 1-2 Forth Code to control the Power I/O Module.

```
HEX
C000 CONSTANT OUTPUT_REGISTER
C001 CONSTANT INPUT_REGISTER

\ bit = a bit mask with 1’s in the position of the bits to be set.
\ module_num = the hardware jumper setting described in Table 1-2.
\ Valid module numbers are 0 to 7.
: SETOUTPUT ( b1/b2 -- | b1 = bit, b2 = module_num )
```

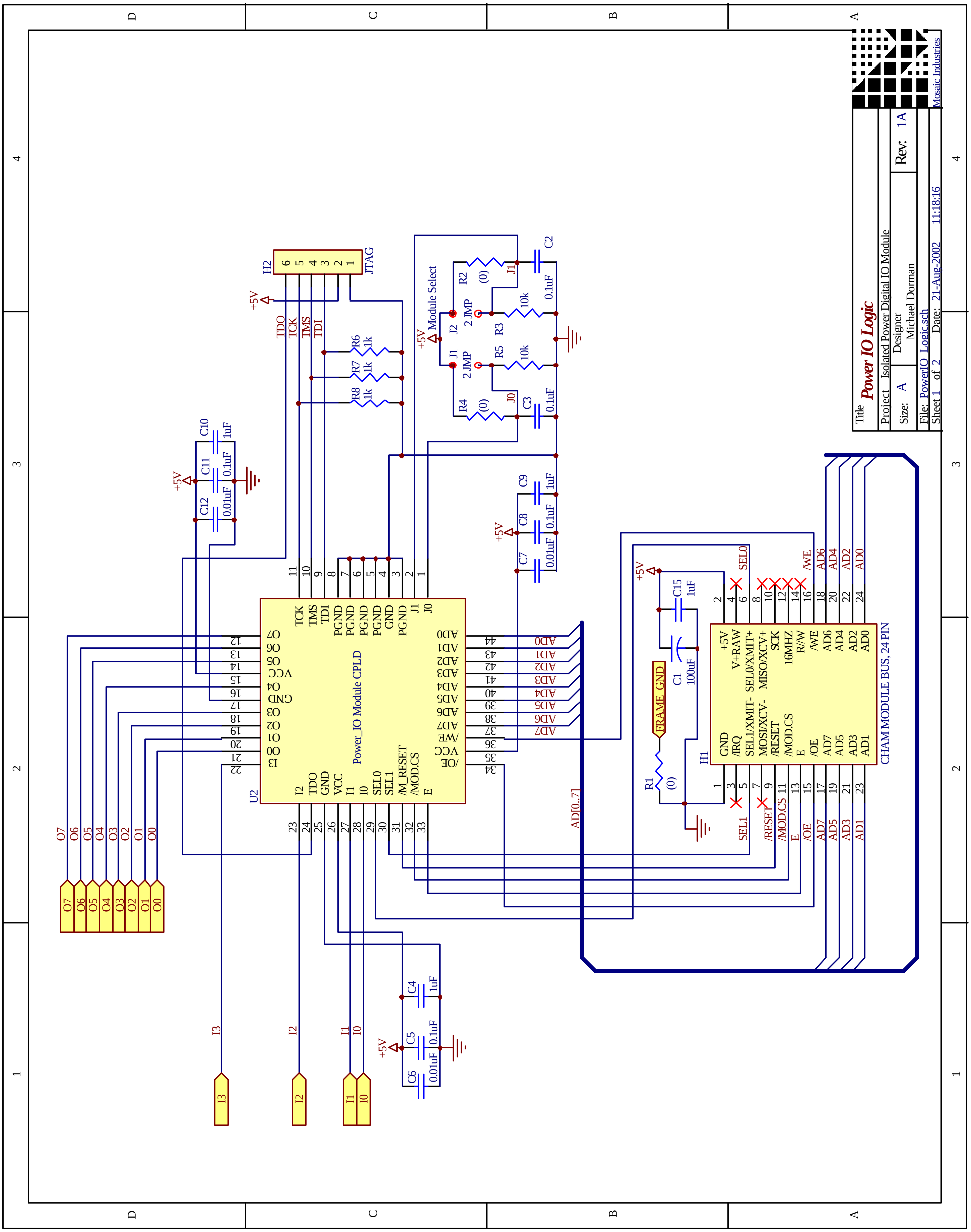
```
locals{ &module &bit }
  &bit OUTPUT_REGISTER &module SET.BITS
;

\ bit = a bit mask with 1's in the position of bits to be cleared.
\ module_num = the hardware jumper setting described in Table 1-2.
\ Valid module numbers are 0 to 7.
: CLEAROUTPUT ( b1/b2 -- | b1 = bit, b2 = module_num )
locals{ &module &bit }
  &bit OUTPUT_REGISTER &module CLEAR.BITS
;

\ module_num = the hardware jumper setting described in Table 1-2.
\ Valid module numbers are 0 to 7.
: READOUTPUT ( b1 -- b2 | b1 = module_num, b2 = output_status )
  OUTPUT_REGISTER SWAP C@
;

\ module_num = the hardware jumper setting described in Table 1-2.
\ Valid module numbers are 0 to 7.
: READINPUT ( b1 -- b2 | b1 = module_num, b2 = input_status )
  INPUT_REGISTER SWAP C@
;
```

Hardware Schematics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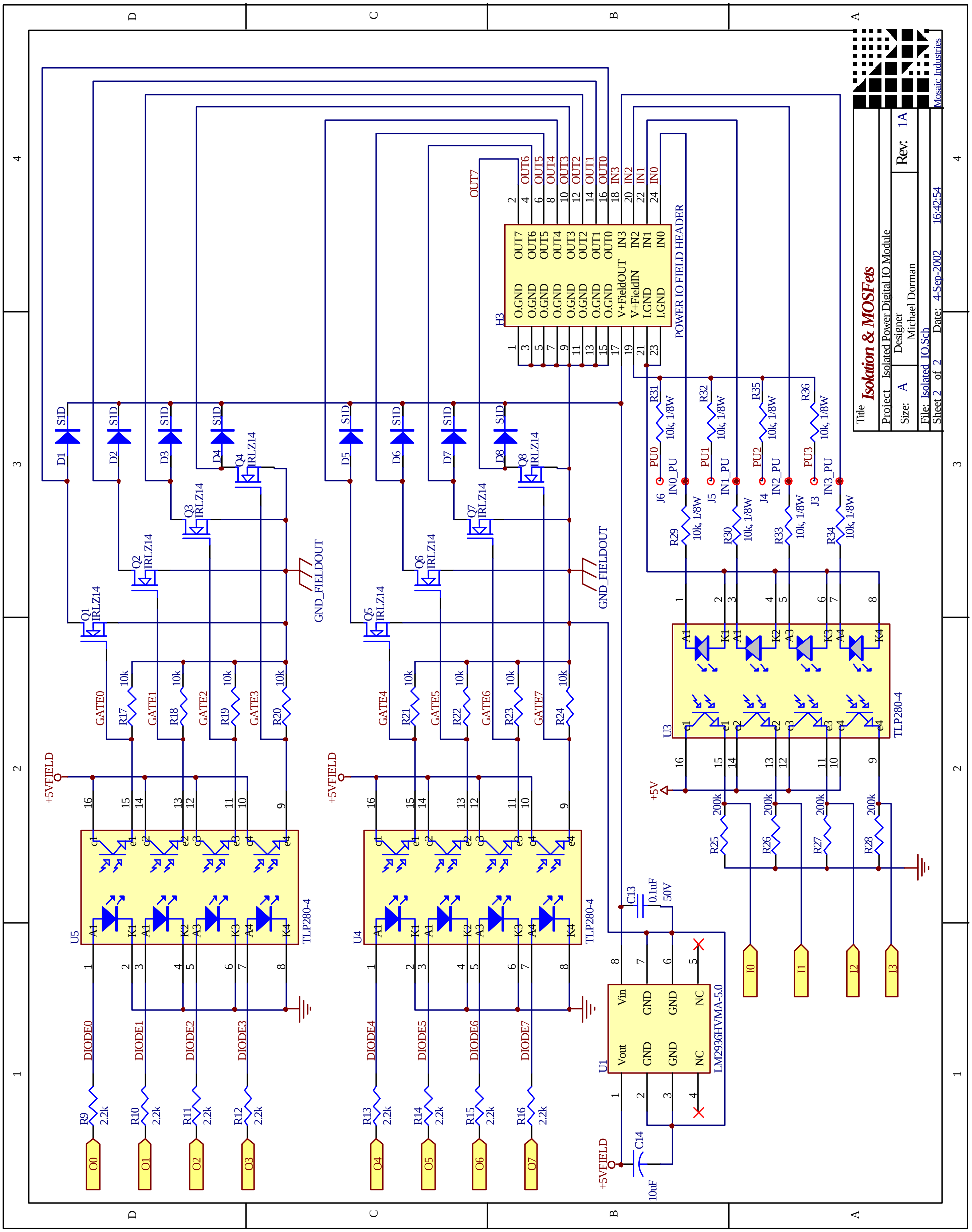
Size: A
Designer Michael Dorman
Rev: 1A
File: PowerIO_Logic.sch
Date: 21-Aug-2002 11:18:16
Sheet 1 of 2
Mosaic Industries
Power_IO Module CPLD
U2
CHAM MODULE BUS, 24 PIN
H1
H2
JTAG
Module Select
FRAME GND
AD[0..7]


Isolation & MOSFets
Title
Project Isolated Power Digital IO Module
Designer Michael Dorman
Size: A
Rev: 1A
File: Isolated_IO.Sch
Sheet 2 of 2
Date: 4-Sep-2002
16:42:54
Mosaic Industries
POWER IO FIELD HEADER
LM2936HVMA-5.0
TLP280-4
GND_FIELDOUT
+5VFIELD
+5V