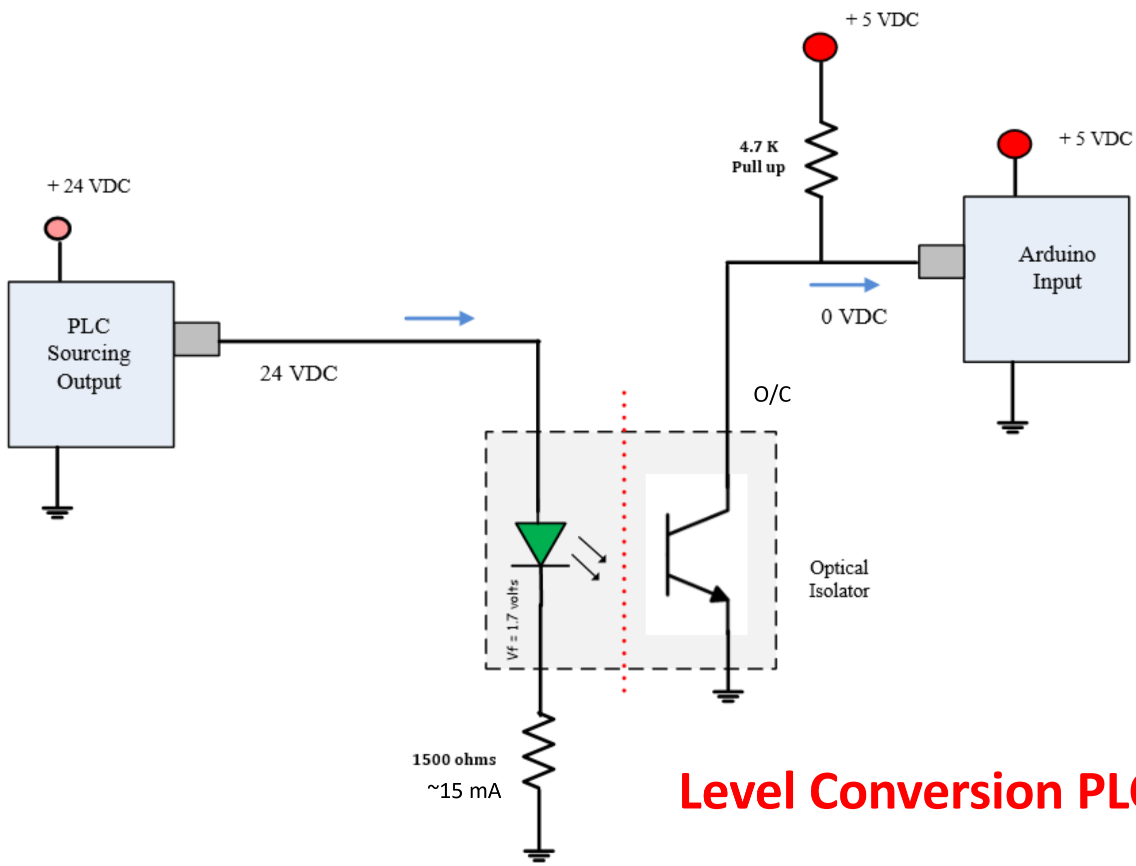
Week 13, 2018 Notes:

Instrumentation Op-Amps and Solid State Relays, Drivers and Interface Circuits

CAM8302E Fall 2018

Final Week: (Total 49 slides):

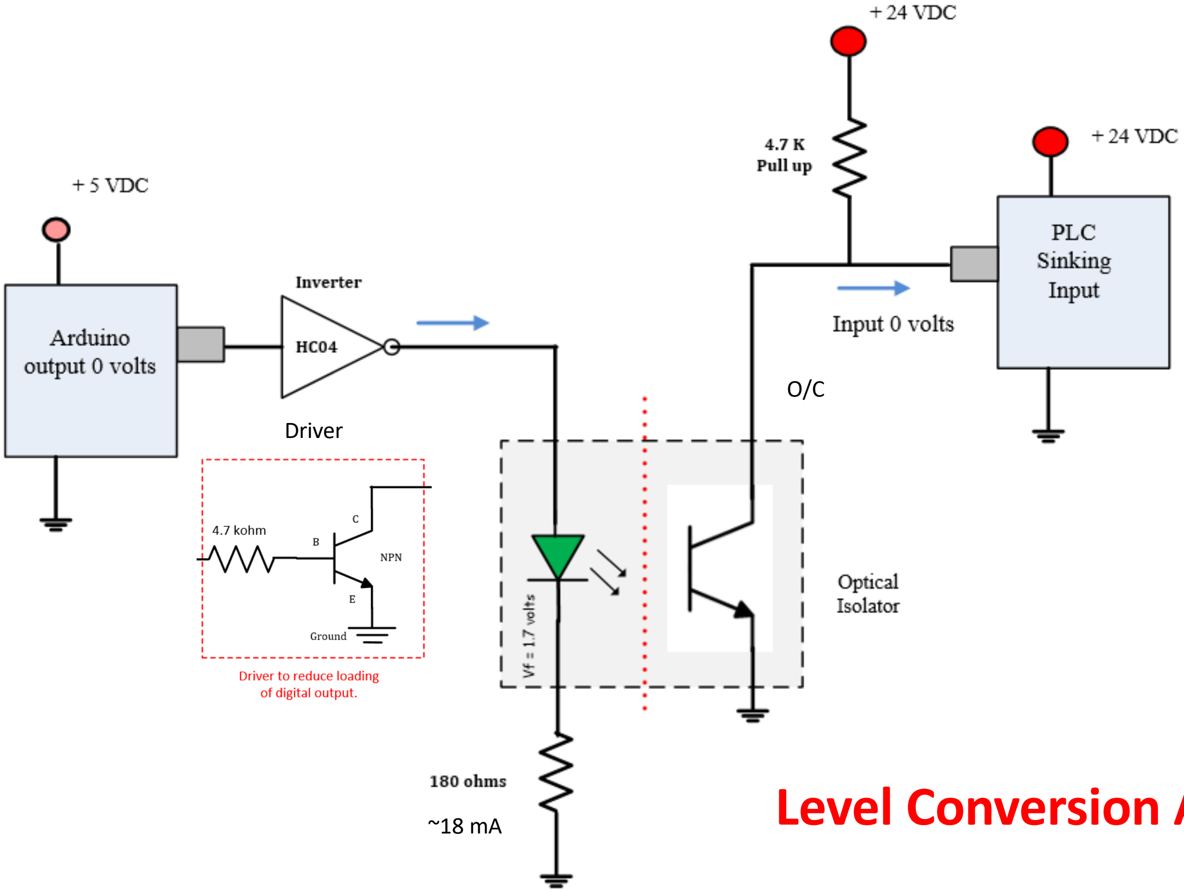


Converting PLC levels to logic levels.

When PLC output equals 24VDC Arduino input equals a logic low.

When PLC output equals 0 volts Arduino input equals 5 volts.

Level Conversion PLC -- Arduino



Converting Arduino output levels to PLC input levels.

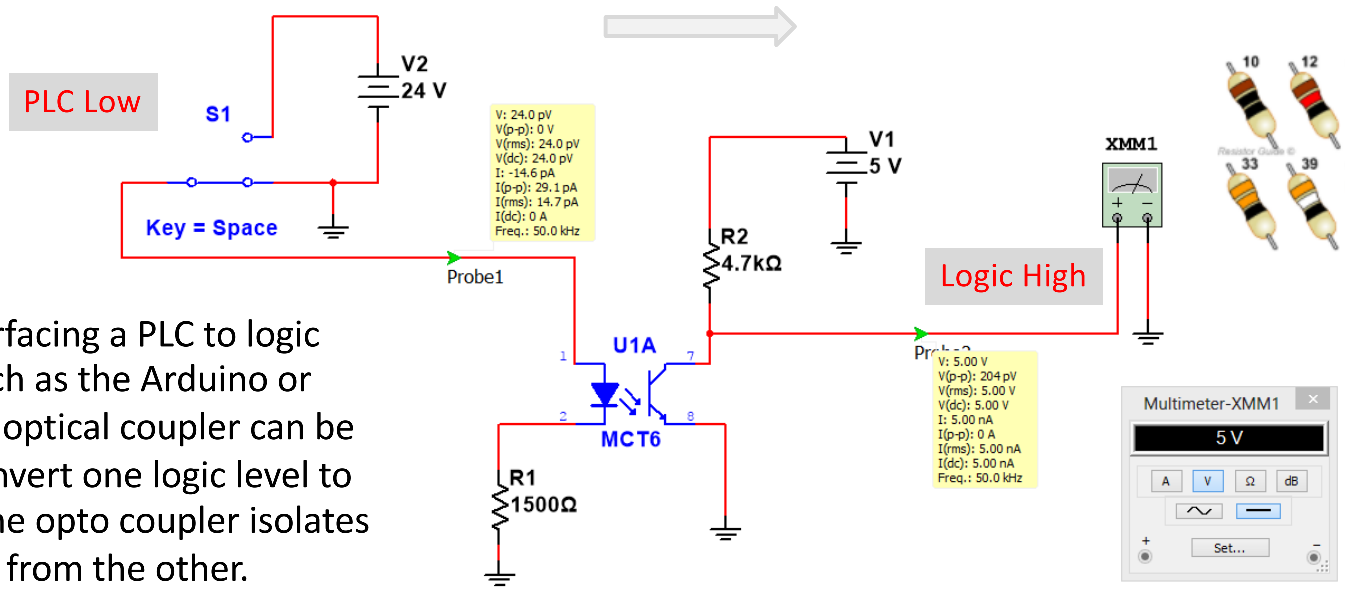
When Arduino output equals 0.0 VDC PLC input input equals 0 volts DC.

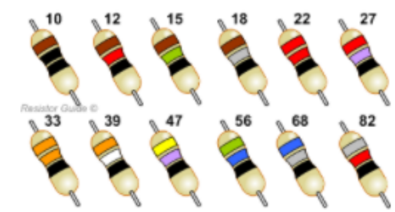
When Arduino output equals 5 volts PLC input equals 24 VDCs.

Level Conversion Arduino ---- Arduino

Level Conversion (PLC to Logic) – Optical Isolation

A PLC signal low. The IR led is off, the transistor is off (open), the pull up resistor provides a logic high of about 5 volts (you could also use 3.3 volts). The IR led must have a current flow between 7 to 15 mA when ON.



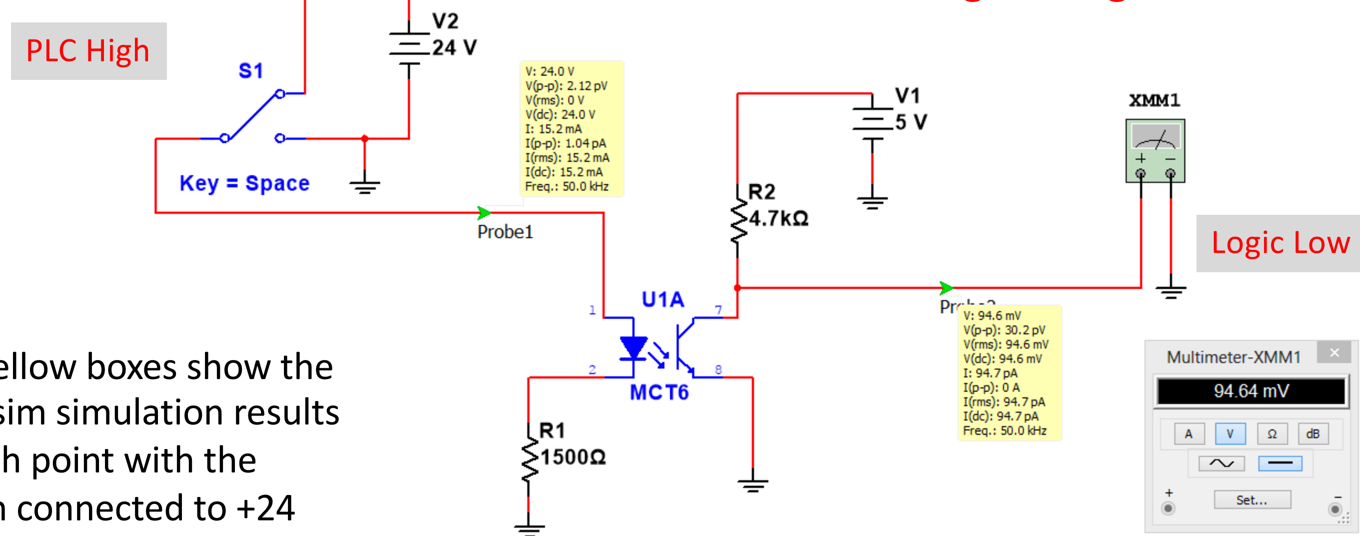


When interfacing a PLC to logic devices such as the Arduino or myDAQ an optical coupler can be used to convert one logic level to another. The opto coupler isolates one device from the other.

Level Conversion (PLC to Logic) – Optical Isolation

A PLC signal high (24 VDC). The IR led is on (current flows through the IR LED), the transistor is on (the cathode is about 0 volts), the signal is a logic low. The 4.7k resistor has a current flow of about 1 mA.

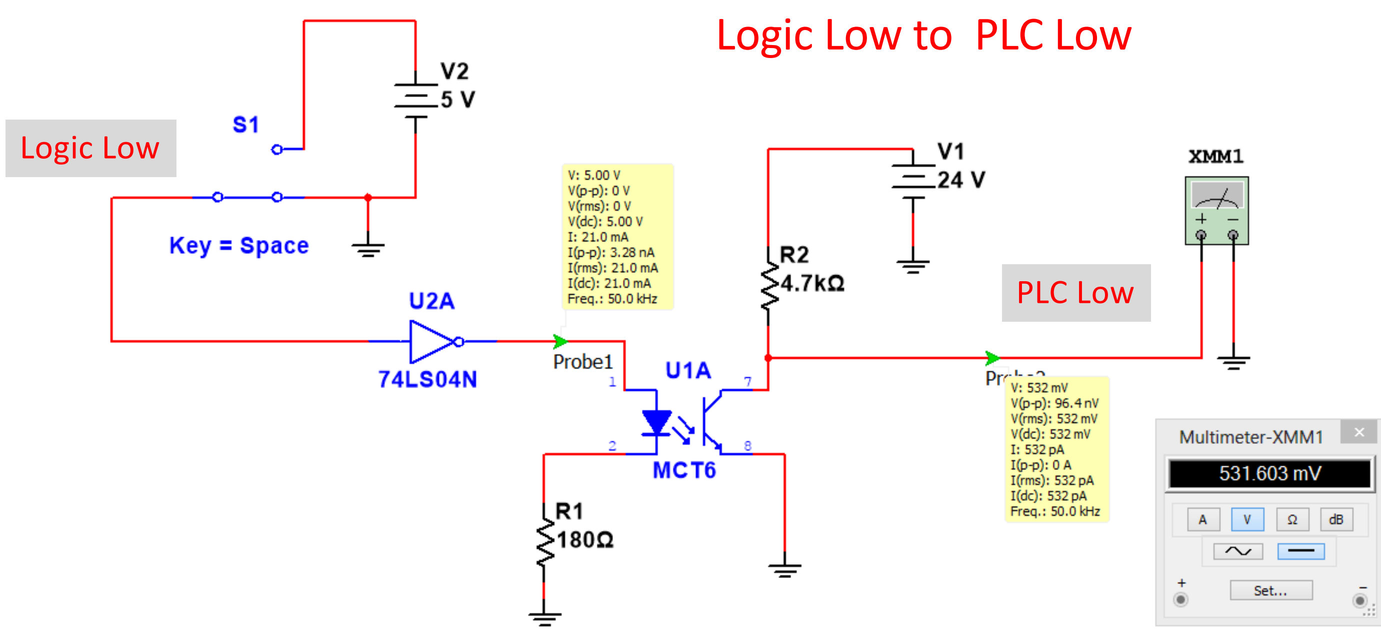
PLC High to logic Low



The yellow boxes show the Multisim simulation results at each point with the switch connected to +24 VDC.

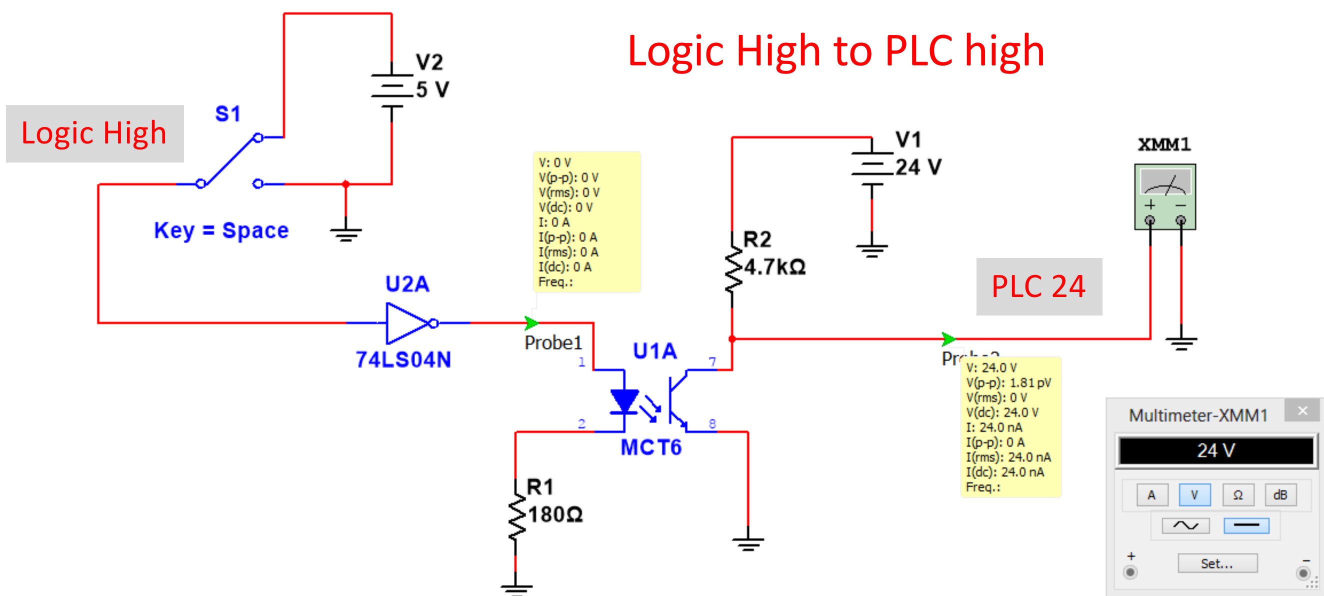
Level Conversion (Logic to PLC) – Optical Isolation

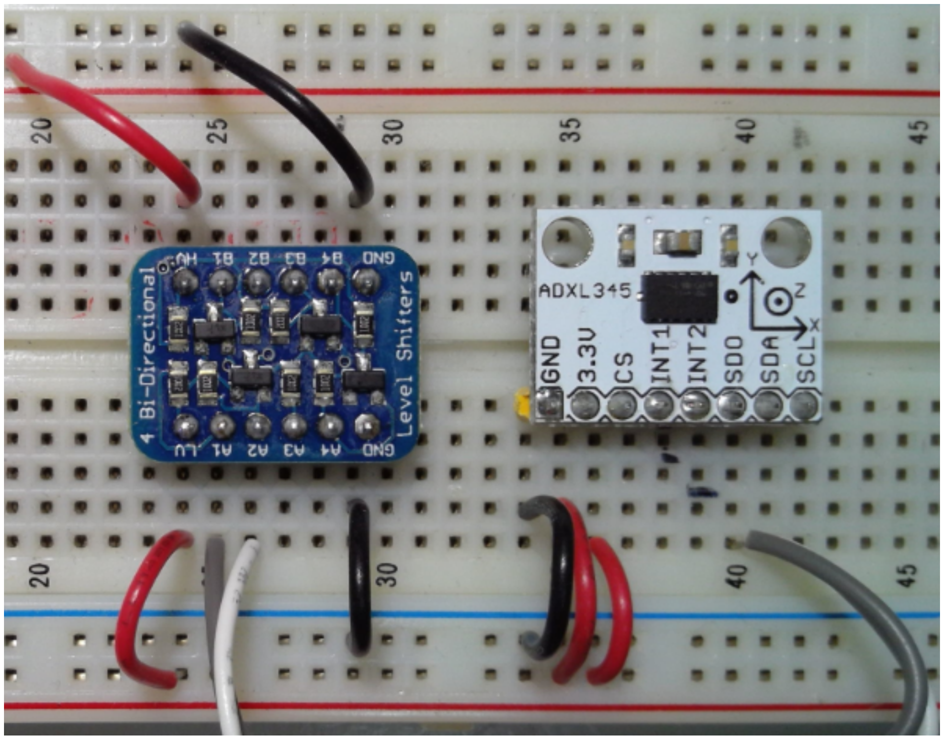
A Logic low signal is applied to the inverter, the inverter output is high, the IR led is on, the transistor acts like a closed switch, the collector provides a PLC low level.

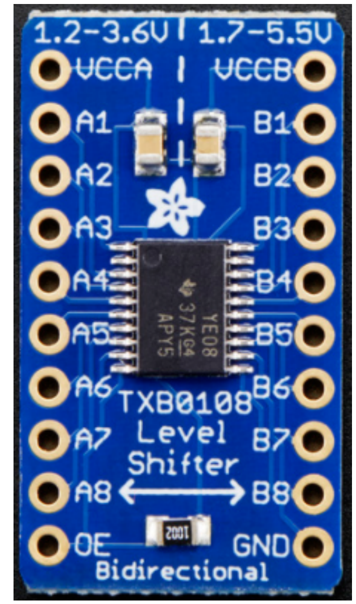


Level Conversion(Logic to PLC) – Optical Isolation

A Logic high signal is applied to the inverter, the inverter output is low, the IR led is off, the transistor acts like a open switch, the pull up resistor provides a PLC high level (24 VDC).

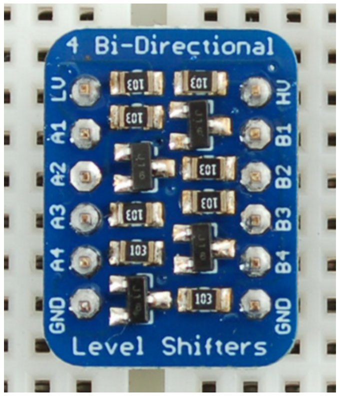


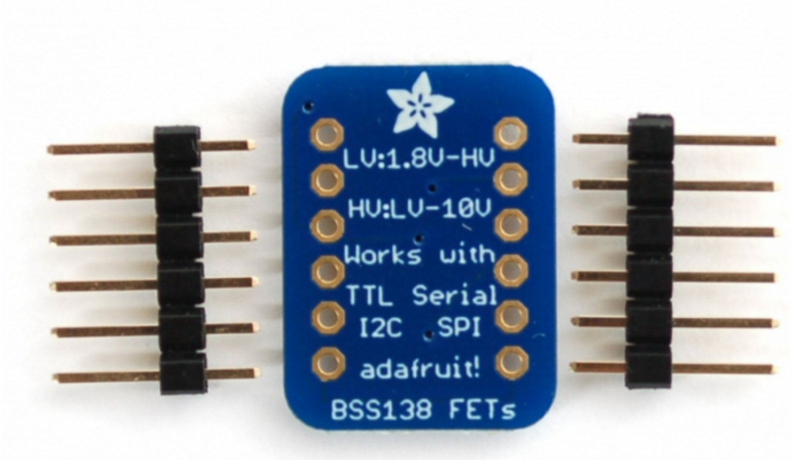




When interfacing the accelerometer to the Arduino a 3.3 volt to TTL level converter is required. This board converts 3.3 levels to TTL and vice versa.

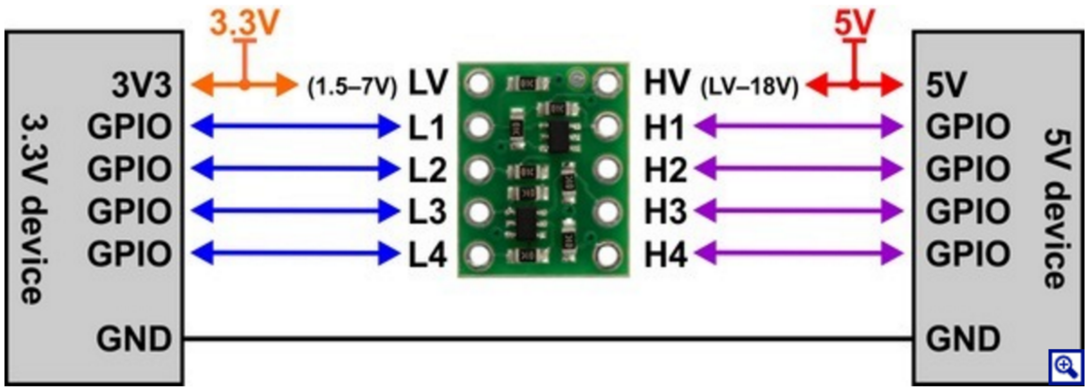
The Bi-Directional level converters allow signals of one logic levels to interface to signals of a second logic level. Each side must be powered by the high logic level.





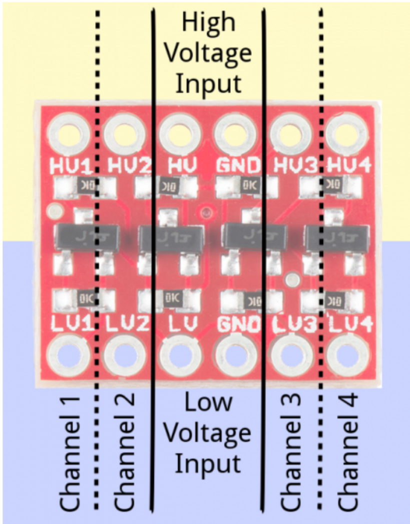
This breakout has 4 BSS138 FETs with 10K pullups. It works down to 1.8V on the low side, and up to 10V on the high side. The 10K's do make the interface a little more sluggish than using a TXB0108 or 74LVC245 so we suggest checking those out if you need high-speed transfer.

Connections



Example wiring diagram for connecting 5 V and 3.3 V devices through the 4-channel bidirectional logic level shifter.

This logic level converter requires two supply voltages: the lower-voltage logic supply (1.5 V to 7 V) connects to the LV pin and the higher-voltage supply (LV to 18 V) connects to the HV pin. The HV supply must be higher than the LV supply for proper operation. Logic low voltages will pass directly from Hx to the corresponding Lx (and vice versa), while logic high voltages will be converted between the HV level to the LV level as the signal passes from Hx to Lx or Lx to Hx.



2.3 Devices with different logic levels connected via the bi-directional level shifter.

The bi-directional level shifter is used to interconnect two sections of an I^2C-bus system, each section with a different supply voltage and different logic levels. In the bus system of Figure 2 the left section has pull-up resistors and devices connected to a 3.3 Volt supply voltage, the right section has pull-up resistors and devices connected to a 5 Volt supply voltage. The devices of each section have I/O's with supply voltage related logic input levels and an open drain output configuration.

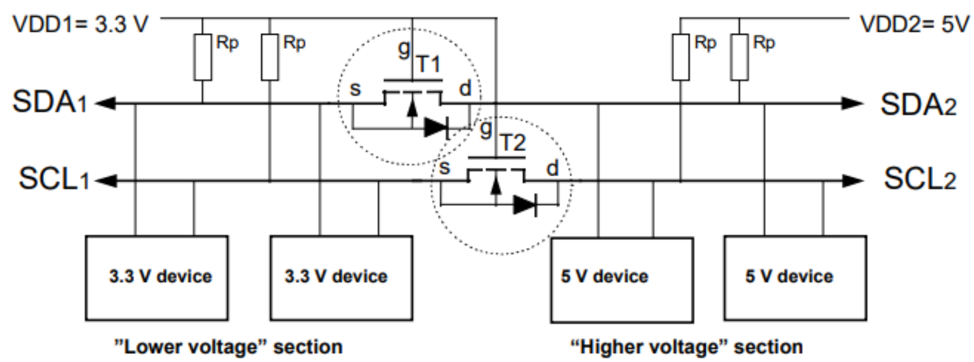


Figure 2. Bi-directional level shifter circuit connects two different voltage sections of an I^2C-bus system.

The level shifter for each bus line is identical and consists of one discrete N-channel enhancement MOS-FET, T1 for the serial data line SDA and T2 for the serial clock line SCL. The gates (g) has to be connected to the lowest supply voltage VDD1 , the sources (s) to the bus lines of the "Lower voltage" section, and the drains (d) to the bus lines of the "Higher voltage" section. Many MOS-FET's have the substrate internally already connected with its source, otherwise it should be done externally. The diode between the drain (d) and substrate is inside the MOS-FET present as n-p junction of drain and substrate.

2.3.1 Description of the level shift operation.

For the level shift operation three states has to be considered:

- State 1. No device is pulling down the bus line and the bus line of the "Lower voltage" section is pulled up by its pull-up resistors Rp to 3.3 V. The gate and the source of the MOS-FET are both at 3.3 V, so its V_{GS} is below the threshold voltage and the MOS-FET is not conducting. This allows that the bus line at the "Higher voltage" section is pulled up by its pull-up resistor Rp to 5V. So the bus lines of both sections are HIGH, but at a different voltage level.
- State 2. A 3.3 V device pulls down the bus line to a LOW level. The source of the MOS-FET becomes also LOW, while the gate stay at 3.3 V. The V_{GS} rises above the threshold and the MOS-FET becomes conducting. Now the bus line of the "Higher voltage" section is also pulled down to a LOW level by the 3.3 V device via the conducting MOS-FET. So the bus lines of both sections become LOW at the same voltage level.

- State 3. A 5 V device pulls down the bus line to a LOW level. Via the drain-substrate diode of the MOS-FET the "Lower voltage" section is in first instance pulled down until V_{GS} passes the threshold and the MOS-FET becomes conducting. Now the bus line of the "Lower voltage" section is further pulled down to a LOW level by the 5 V device via the conducting MOS-FET. So the bus lines of both sections become LOW at the same voltage level.

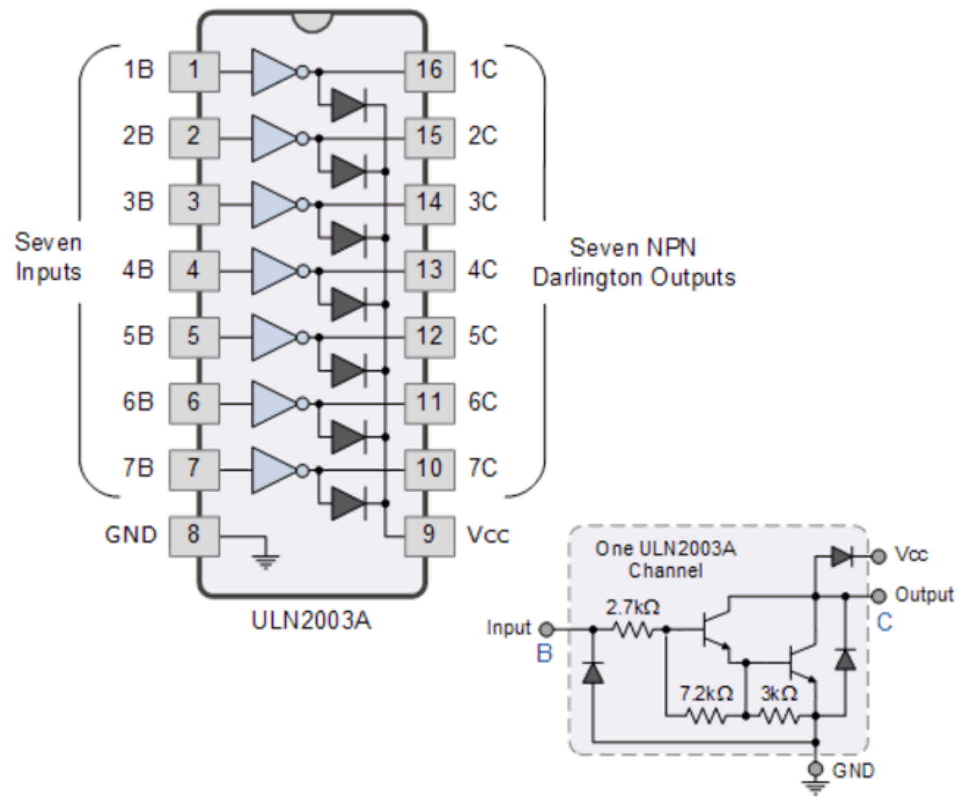
ULN2003 Darlington Transistor Array

The ULN2003A is a very common high voltage high current driver.

The input current is less than 1 mA when driven by TTL or LVTTL circuits. There are 7 outputs capable of driving inductive loads up to 500 mA on each channel.

When driving inductive loads pin 9 must be connected to the positive supply of the inductive device.

The diodes suppress the spike that occurs when an inductive device is turned off.



Recommended alternative parts

- TPL7407L - Better power efficiency, lower leakage and operating temperature range up to 125C

ULN2003A

Description

The ULx200xA devices are high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads.

The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs can be paralleled for higher current capability.

Features

- 500-mA-Rated Collector Current (Single Output)
- High-Voltage Outputs: 50 V
- Output Clamp Diodes
- Inputs Compatible With Various Types of Logic
- Relay-Driver Applications

View more

Parametrics

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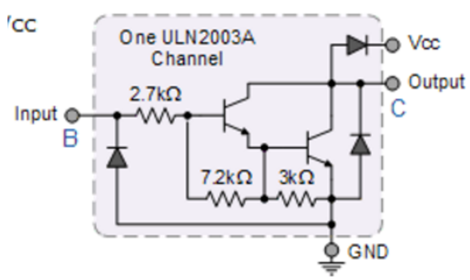
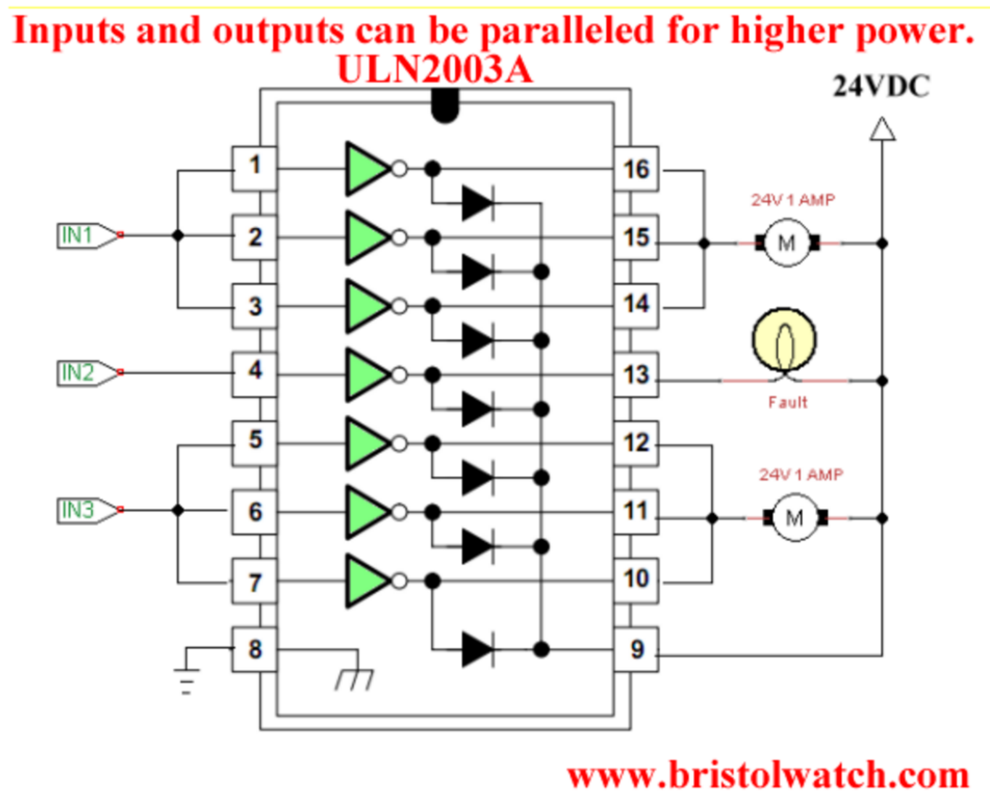
	ULN2003A	ULN2003AI	ULN2003B	ULN2003LV	ULN2003V12	ULN2004A
Drivers Per Package	7	7	7	7	7	7
Switching Voltage (Max) (V)	50	50	50	8	16	50
Peak Output Current (mA)	500	500	500	1000	1000	500
Delay Time (Typ) (ns)	250	250	250	80	80	250
Output Voltage (Max) (V)	50	50	50	8	16	50
Input Compatibility	CMOS TTL	CMOS TTL	CMOS TTL	CMOS	CMOS	CMOS

The ULN2003A inputs and outputs can be paralleled to drive high power outputs.

When driving inductive loads the supply voltage must be connected to pin 9 (this connects the internal “Flywheel diodes”).

The ULN2003A uses a Darlington transistor. This arrangement gives the circuit a very high Beta value. A low current at the input (about 1 mA can drive about 500 mA at the output.





Solid State Relays

Solid state relays have no moving parts, they are very reliable and are long lasting.

The controlling circuit can be low voltage and low current. The SSR is designed to interface to logic circuits.

SSR (solid state relays) can be used to control high voltage and high current AC and DC circuits.

SSR use internal optical isolations to protect the low voltage circuits.

They come in many different versions.

- 120 and 240 VAC outputs
- 5, 12, 24 volt DC outputs
- 120 and 240 VAC input
- 5-60 VDC input
- 1 amp to >100 amps outputs

The Solid State Relay.

While the **electromechanical relay** (EMR) are inexpensive, easy to use and allow the switching of a load circuit controlled by a low power, electrically isolated input signal, one of the main disadvantages of an electromechanical relay is that it is a “mechanical device”, that is it has moving parts so their switching speed (response time) due to physically movement of the metal contacts using a magnetic field is slow.

Over a period of time these moving parts will wear out and fail, or that the contact resistance through the constant arcing and erosion may make the relay unusable and shortens its life. Also, they are electrically noisy with the contacts suffering from contact bounce which may affect any electronic circuits to which they are connected.

To overcome these disadvantages of the electrical relay, another type of relay called a **Solid State Relay** or (**SSR**) for short was developed which is a solid state contactless, pure electronic relay. The solid state relay being a purely electronic device has no moving parts within its design as the mechanical contacts have been replaced by power transistors, thyristors or triac’s. The electrical separation between the input control signal and the output load voltage is accomplished with the aid of an opto-coupler type Light Sensor.

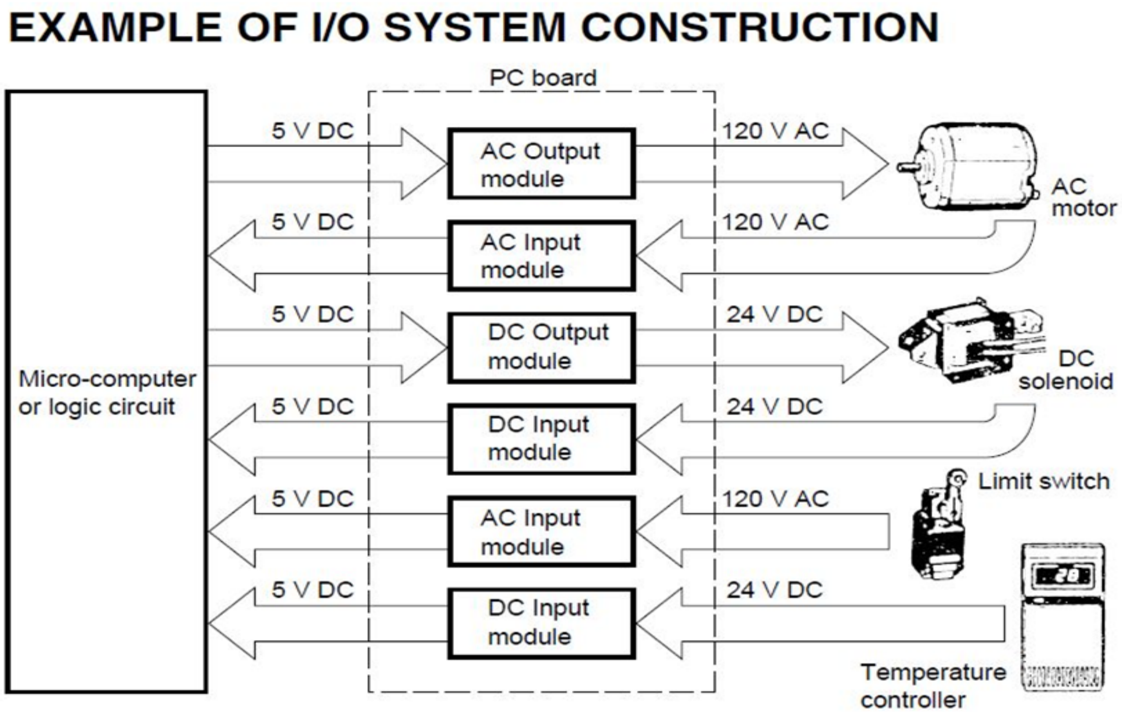
Solid State Relay Applications

Controlling Heater Elements in a Plastic Moulding Machine

Controlling the Motor in an Electric Hoist

GA3
Solid-State Relay

Solid State Relay Applications



Logic controlling an AC load with high voltage and currents.

Logic controlling a DC load with high voltage and currents.

Logic measuring the status of a limit switch that uses 120 VAC.

Logic measuring the status of a temperature Sensor outputting 0 volts or 24V DC.

Solid State Relay Packages

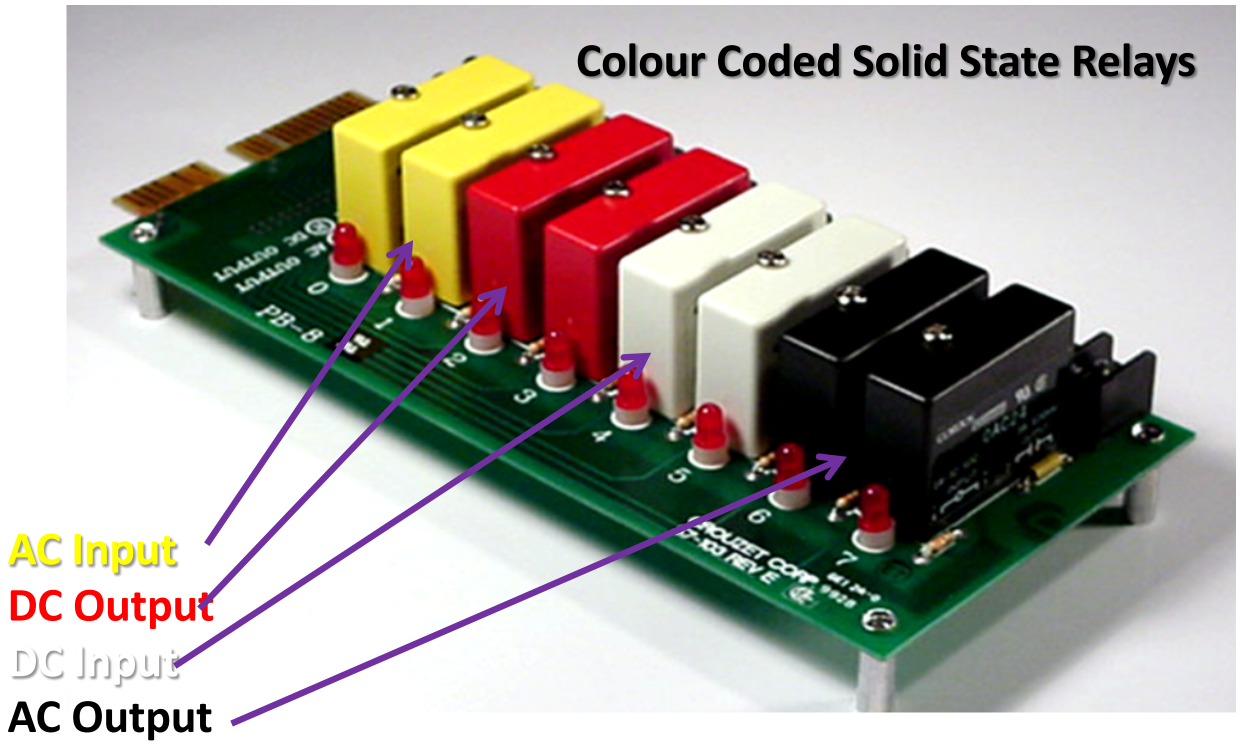
Solid State Relays

Each solid state relay type is colour coded.
The yellow device measures and AC input signal and outputs a logic low or high.

The red device outputs a high voltage DC signal that is controlled using a logic signal.

The white device measures a high voltage DC signal and converts it to a logic level.

The black device (most common) controls an AC signal using logic levels)



The AC type Solid State Relay turns “ON” at the zero crossing point of the AC sinusoidal waveform, prevents high inrush currents when switching inductive or capacitive loads while the inherent turn “OFF” feature of Thyristors and Triacs provides an improvement over the arcing contacts of the electromechanical relays.

Like the electromechanical relays, a Resistor-Capacitor (RC) snubber network is generally required across the output terminals of the SSR to protect the semiconductor output switching device from noise and voltage transient spikes when used to switch highly inductive or capacitive loads. In most modern SSR’s this RC snubber network is built as standard into the relay itself reducing the need for additional external components.

Non-zero crossing detection switching (instant “ON”) type SSR’s are also available for phase controlled applications such as the dimming or fading of lights at concerts, shows,lighting etc, or for motor speed control type applications.

ElectronicsTutorials

The Basics of SSRs (Solid-State Relays): The Switching Device

June 16, 2017 by Steve Arar

This article provides an introduction to the basic operation of solid-state relays with a focus on the output devices in today's SSRs.

There are many circumstances in which we need to control a high current/voltage load based on the operation of a low-power circuit, such as when using the 5V output of a microcontroller to turn on a 10A, 240V load. In these cases, it is necessary to provide sufficient isolation between the high-power and low-power parts of the system. Different types of relays such as electromechanical relays (EMR), reed relays, and solid-state relays (SSR) can be used to achieve this goal.

While EMRs are still widely used, they have several disadvantages in comparison to SSRs. This article briefly reviews the drawbacks of EMRs and gives some details regarding the basic operation of SSRs, with emphasis on the output devices.

ALL ABOUT CIRCUITS

EMRs and Their Drawbacks

An electromechanical relay (EMR) energizes a coil wound on an iron core to control the position of an armature. For a normally open output, the energized coil forces the armature to put the electrical contacts into the ON state. When the coil is de-energized, springs can move the contacts back to the OFF position.

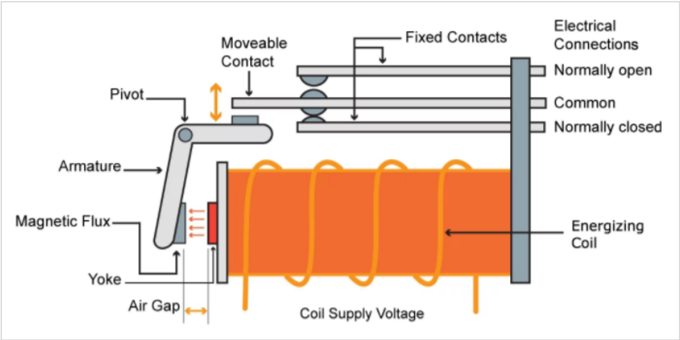


Figure 1. *In an EMR, the energized coil moves the armature to either connect or disconnect the output terminals. Image adapted from electronics-tutorials.*

An electromechanical relay is robust and versatile. However, it takes up more room and is slower than an SSR. Typically, an EMR needs 5 to 15 ms to switch and settle—a delay which is not acceptable in some applications. Moreover, due to their moving parts, EMRs have a shorter operational lifetime.

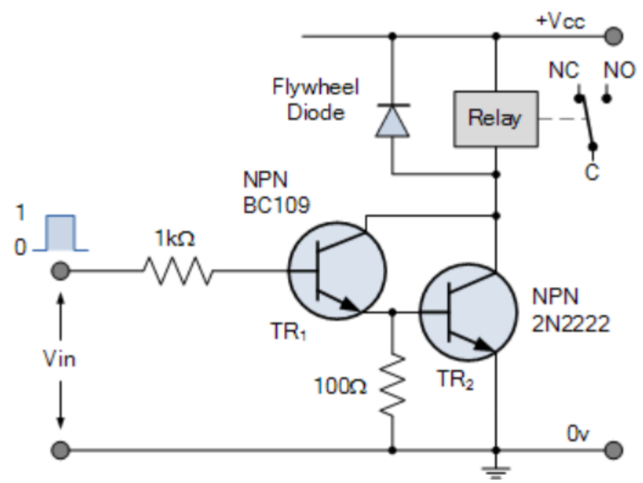
An electromechanical relay uses magnetic fields to provide isolation; an SSR, in contrast, achieves this goal generally through opto-coupling. As shown in Figure 2, in an SSR a small input voltage, typically 3 to 32 VDC, is used to illuminate an LED. When the LED is turned on, an output photo-sensitive device, such as a TRIAC, turns on and conducts current.

NPN Darlington Relay Switch Circuit

The previous NPN transistor relay switch circuit is ideal for switching small loads such as LED's and miniature relays. But sometimes it is required to switch larger relay coils or currents beyond the range of a BC109 general purpose transistor and this can be achieved using **Darlington Transistors**.

The sensitivity and current gain of a relay switch circuit can be greatly increased by using a Darlington pair of transistors in place of a single switching transistor. Darlington Transistor pairs can be made from two individually connected Bipolar Transistors as shown or available as one single device with standard: Base, Emitter and Collector connecting leads.

The two NPN transistors are connected as shown so that the Collector current of the first transistor, TR1 becomes the Base current of the second transistor TR2. The application of a positive base current to TR1 automatically turns "ON" the switching transistor, TR2.



NPN Relay Switch Circuit

A typical relay switch circuit has the coil driven by a NPN transistor switch, TR1 as shown depending on the input voltage level. When the Base voltage of the transistor is zero (or negative), the transistor is cut-off and acts as an open switch. In this condition no Collector current flows and the relay coil is de-energised because being current devices, if no current flows into the Base, then no current will flow through the relay coil.

If a large enough positive current is now driven into the Base to saturate the NPN transistor, the current flowing from Base to Emitter (B to E) controls the larger relay coil current flowing through the transistor from the Collector to Emitter.

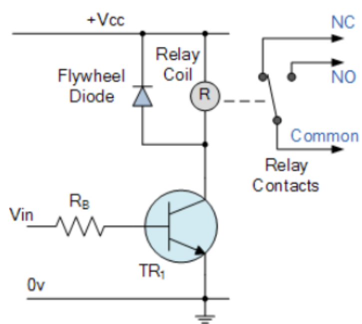
For most bipolar switching transistors, the amount of relay coil current flowing into the Collector would be somewhere between 50 to 800 times that of the required Base current to drive the transistor into saturation. The current gain, or beta value (β) of the general purpose BC109 shown is typically about 290 at 2mA (Datasheet).

Note that the relay coil is not only an electromagnet but it is also an inductor. When power is applied to the coil due to the switching action of the transistor, a maximum current will flow as a result of the DC resistance of the coil as defined by Ohms Law, (I = V/R). Some of this electrical energy is stored within the relay coil's magnetic field.

When the transistor switches "OFF", the current flowing through the relay coil decreases and the magnetic field collapses. However the stored energy within the magnetic field has to go some where and a reverse voltage is developed across the coil as it tries to maintain the current in the relay coil. This action produces a high voltage spike across the relays coil that can damage the switching NPN transistor if allowed to build up.

So in order to prevent damage to the semiconductor transistor, a "flywheel diode", also known as a freewheeling diode, is connected across the relay coil. This flywheel diode clamps the reverse voltage across the coil to about 0.7V dissipating the stored energy and protecting the switching transistor. Flywheel diodes are only applicable when the supply is a polarized DC voltage. An AC coil requires a different protection method, and for this an RC snubber circuit is used.

As the current flows through the coil a self induced magnetic field is generated around it. When the current in the coil is turned "OFF", a large back emf (electromotive force) voltage is produced as the magnetic flux collapses within the coil (transformer theory). This induced reverse voltage value may be very high in comparison to the switching voltage, and may damage any semiconductor device such as a transistor, FET or micro-controller used to operate the relay coil.



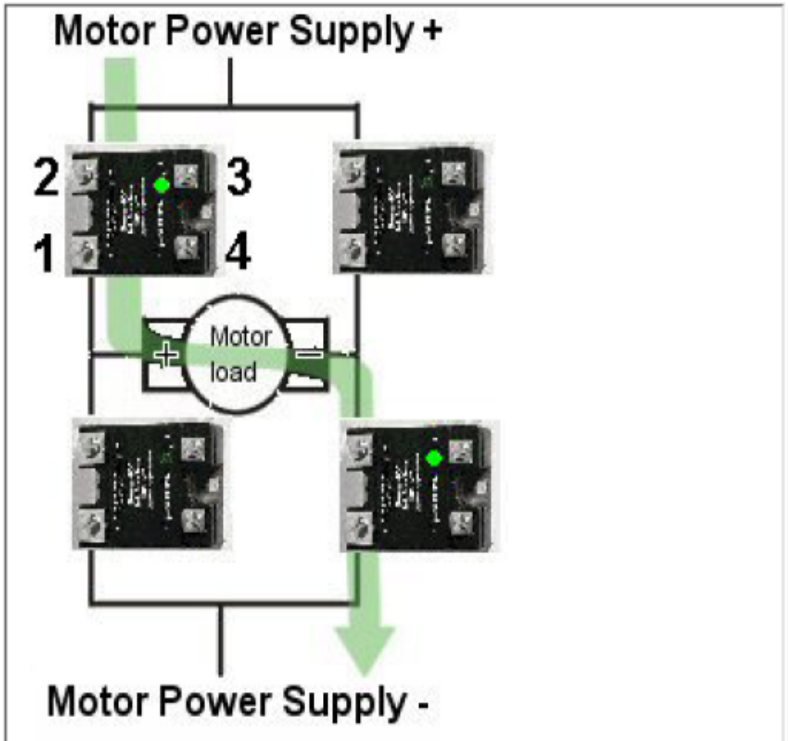
One way of preventing damage to the transistor or any switching semiconductor device, is to connect a reverse biased diode across the relay coil.

When the current flowing through the coil is switched "OFF", an induced back emf is generated as the magnetic flux collapses in the coil.

This reverse voltage forward biases the diode which conducts and dissipates the stored energy preventing any damage to the semiconductor transistor.

When used in this type of application the diode is generally known as a **Flywheel Diode**, **Free-wheeling Diode** and even **Fly-back Diode**, but they all mean the same thing. Other types of inductive loads which require a flywheel diode for protection are solenoids, motors and inductive coils.

Solid State Relay H-Bridge



Example: how to make an H Bridge for a reversing VDC motor application or alternative energy applications:

First you make an H bridge with 4 Power-io units. Power-io terminals 1 and 2 = the power terminals for the motor connections. Polarity is important. Terminal 2 is towards the positive power supply and terminal 1 is towards the negative power supply.

Use a HDD product where the voltage rating is at least twice the motor's rating. For example: a HDD-06V75 is rated for 60 volts DC so it would be a good choice for a 12 volt or 24 volt motor. Determine the maximum amperage inrush required for the motor and make sure that it is with-in the capability of the Power-io unit. The HDD-06V75 is rated for 75 amps when on a properly sized heat sink.

POWER-IO

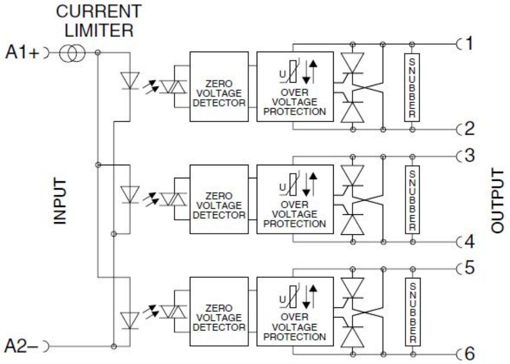
Three-Phase Solid State Relay

Crouzet

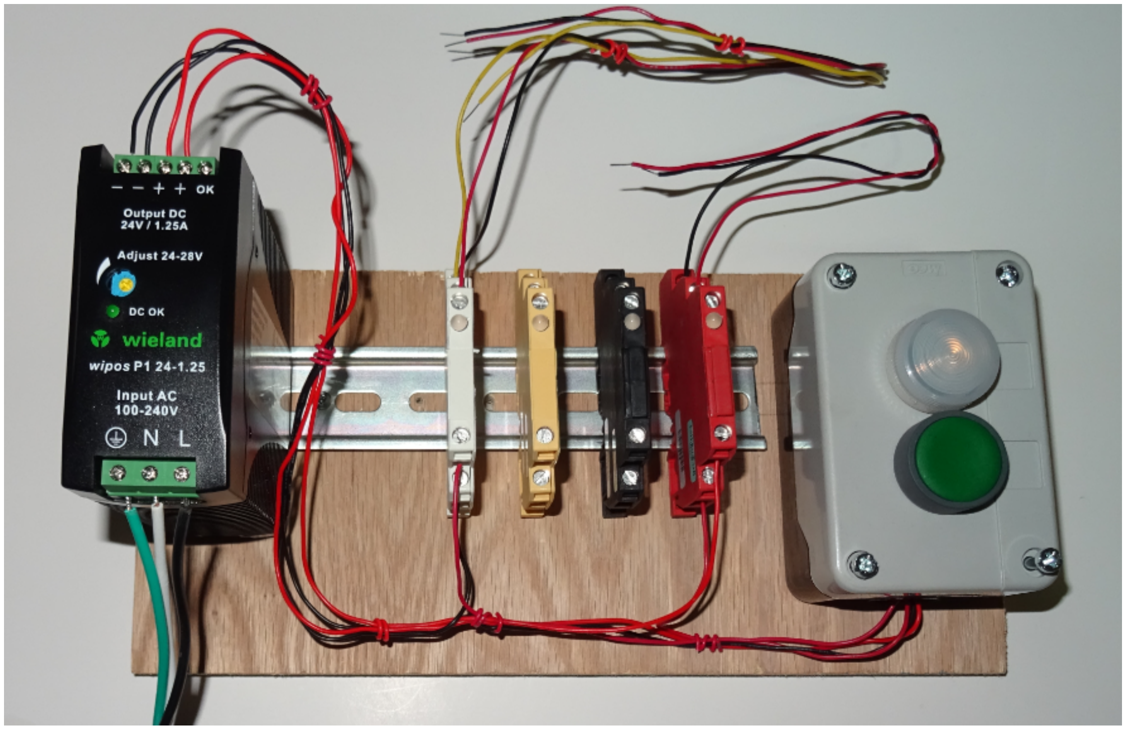
SOLID STATE RELAYS

THREE-PHASE SOLID STATE RELAYS

- 10, 25 and 45 Amps Output Per Channel Available
- 24 to 600 VAC Output Voltage Range Suitable for Many Applications
- 1200 Volts Peak Blocking Voltage Helps Protect Against Transients in Harsh Electrical Environments
- Internal RC Snubber Network
- 4000 VAC Optical Isolation
- 4 to 32 Control Voltage for a Wide Variety of Logic Circuit Applications
- Zero Voltage or Random Turn-on
- Industry Standard Package
- UL Recognized (E74183) 10 hp 480 VAC, CSA Certified (LR38545)
- CE Compliant



Various SSR and Power Supply



The modules shown above are used to interface to a PLC.

Black(OAC5) – used to control an AC load using a logic signal.

Red(ODC5) – used to control an DC load using a logic signal.

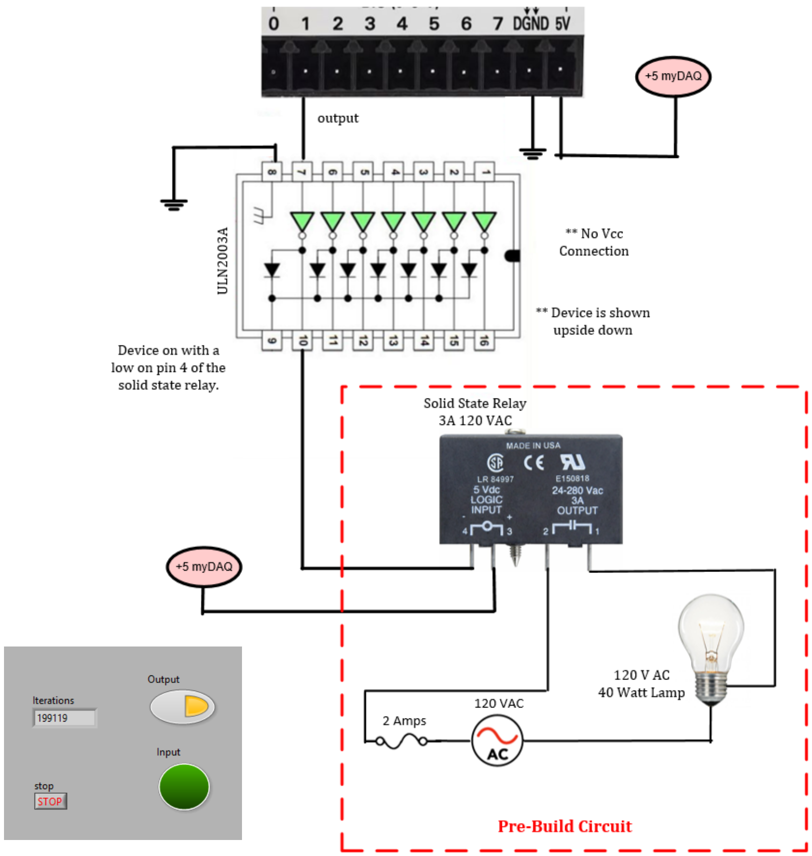
Yellow IAC5 – Measures an AC input voltage and converts it to a logic level.

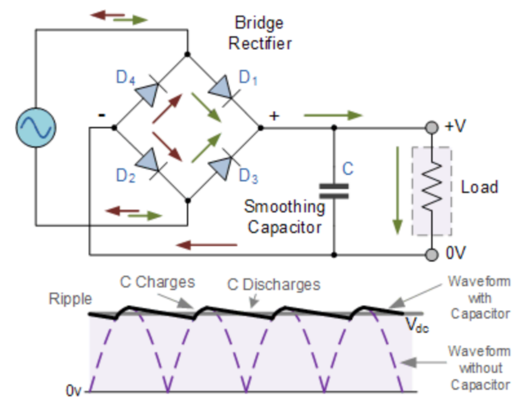
White - (IDC5) – Measures a DC input voltage and converts it to a logic level.

Circuit is required in lab 8.

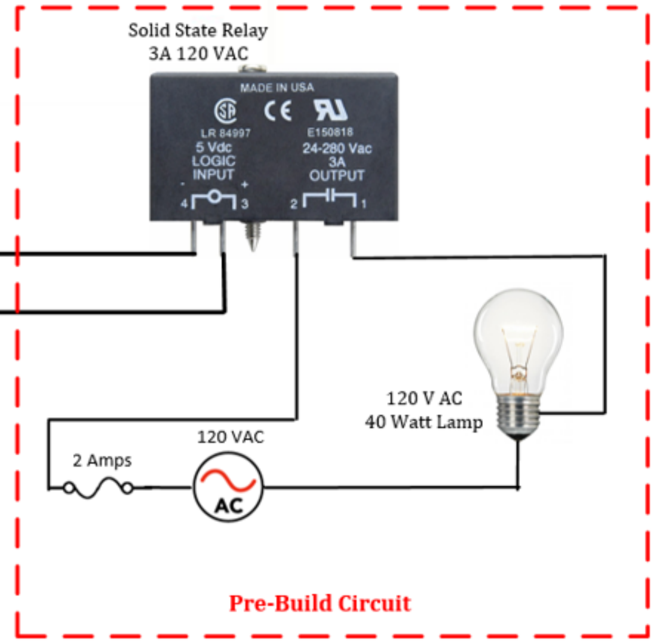
The ULN2003A drivers is added to the digital output on the myDAQ. The specifications for the myDAQ indicate a maximum current of 4 mA. The SSR has a load of about 15 mA when active.

The ULN2003A inputs draw less then 1 mA when controlling the SSR.

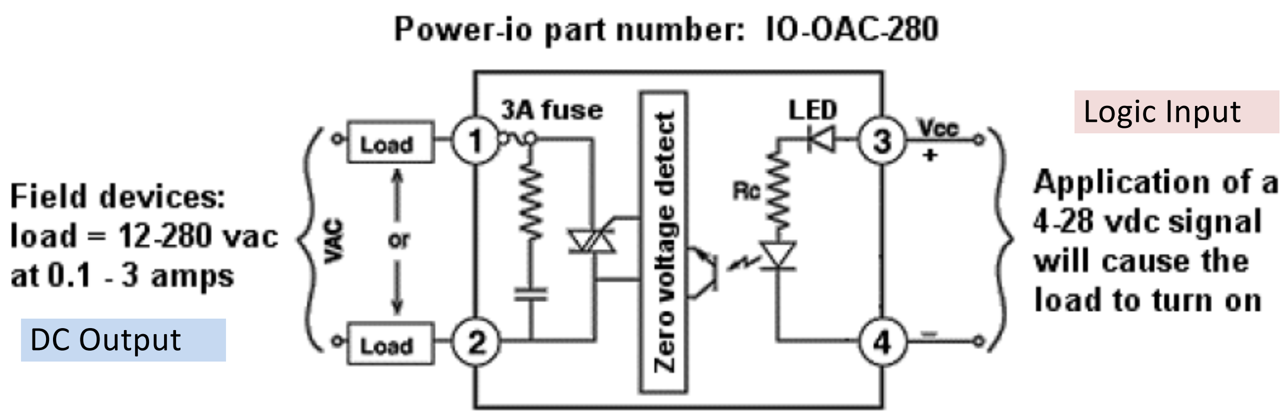




SSR AC Lamp Control



Lamp and SSR used in lab 8.



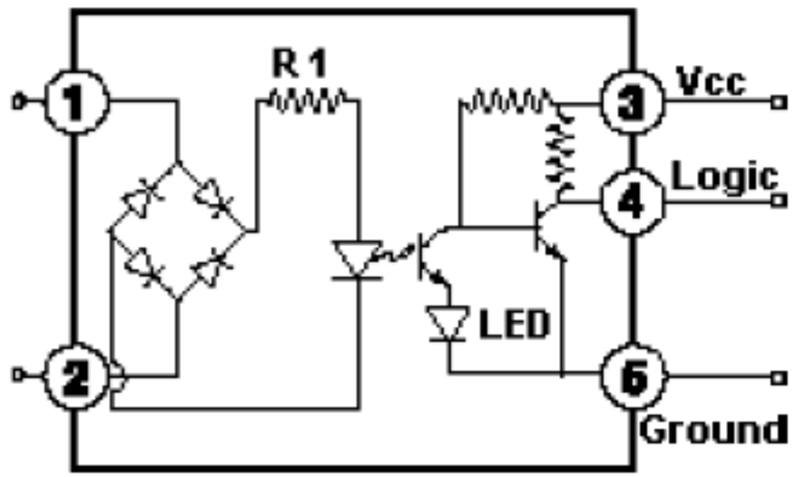
OAC5

Black(OAC5) – used to control an AC load using a logic signal.

The circuit connected to pins 3 and 4 are the inputs to the solid state device. When a logic voltage is applied to the input the IR LED activates the zero crossing detector. The output of the zero crossing detector then energizes a ”Triac” allowing current to flow through the output load. The load voltage can be as high as 280 VAC with a current up to 3 amps.

IO-IAC-280-P : An AC field input on terminals 1 and 2 = the voltage of terminal 4 will change from ground (terminal 5) to vcc (terminal 3)

AC Input



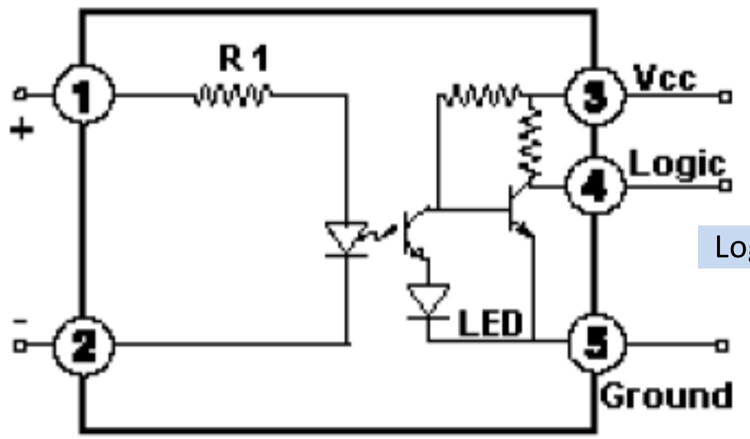
Logic Input

IAC5

Yellow IAC5 – Measures an AC input voltage and converts it to a logic level.

The circuit connected to pins 1 and 2 converts the AC input signal to DC it is called a bridge rectifier circuit. The output of the rectifier turns on the LED which acts as the optical isolation to the base of the photo transistor. The output switches between low and high and connects to the input of the Arduino or the myDAQ.

IO-IDC-028-P : A DC field input on terminals 1 and 2 = the voltage of terminal 4 will change from ground (terminal 5) to vcc (terminal 3)



DC Input

Logic Output

IDC5

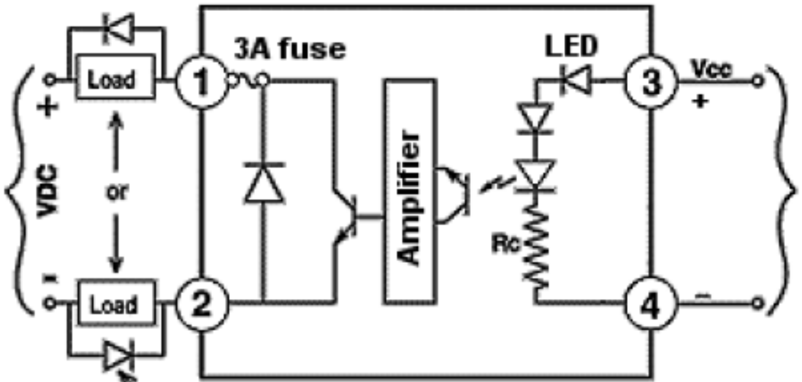
White - (IDC5) – Measures a DC input voltage and converts it to a logic level.

(IDC5) The circuit connected to pins 1 and 2 turn on an IR LED when a DC voltage is applied to the input. The output controls the logic level being applied to pin 4. Pins 3 and 5 connect to a logic supply.

Power-io part number: IO-ODC-060

Field devices:
load = 5-60 vdc
at 0.1 - 3 amps

DC Output



Diode must be used with inductive loads

Logic Input

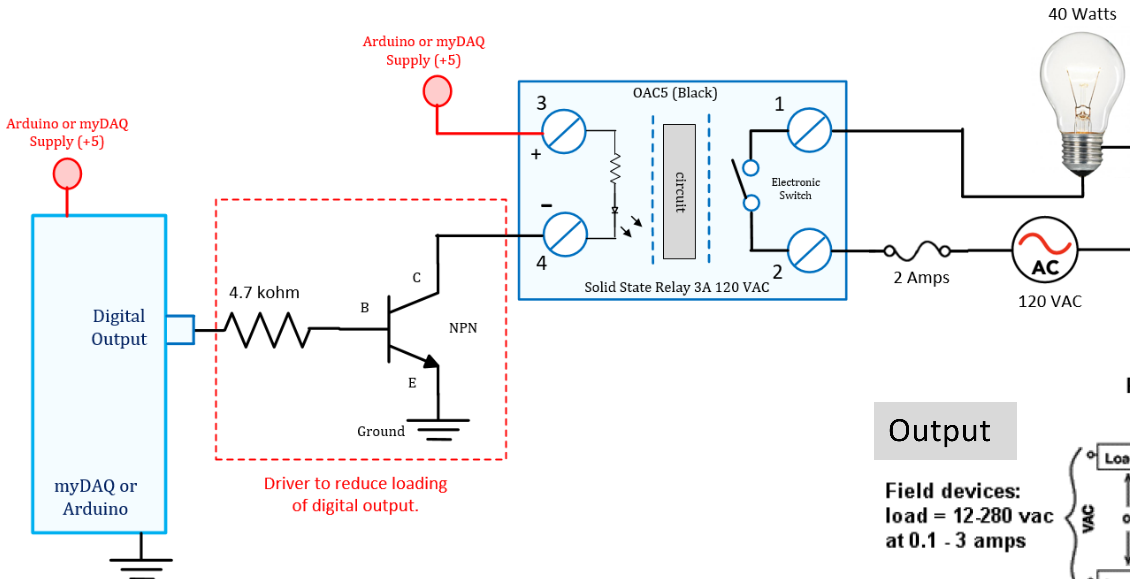
Application of a
4-28 vdc signal
will cause the
load to turn on

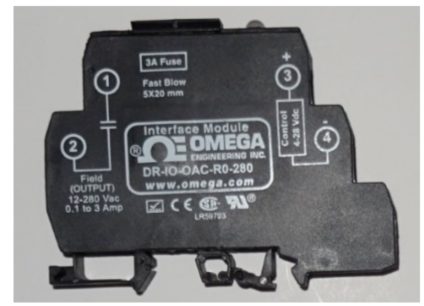
ODC5

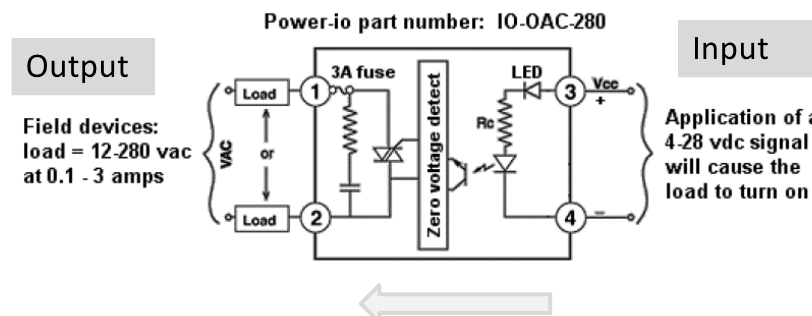
Red(ODC5) – used to control an DC load using a logic signal.

The circuit connected to pins 3 and 4 energizes an IR LED. The output controls a DC load. Use diodes if the load is inductive.

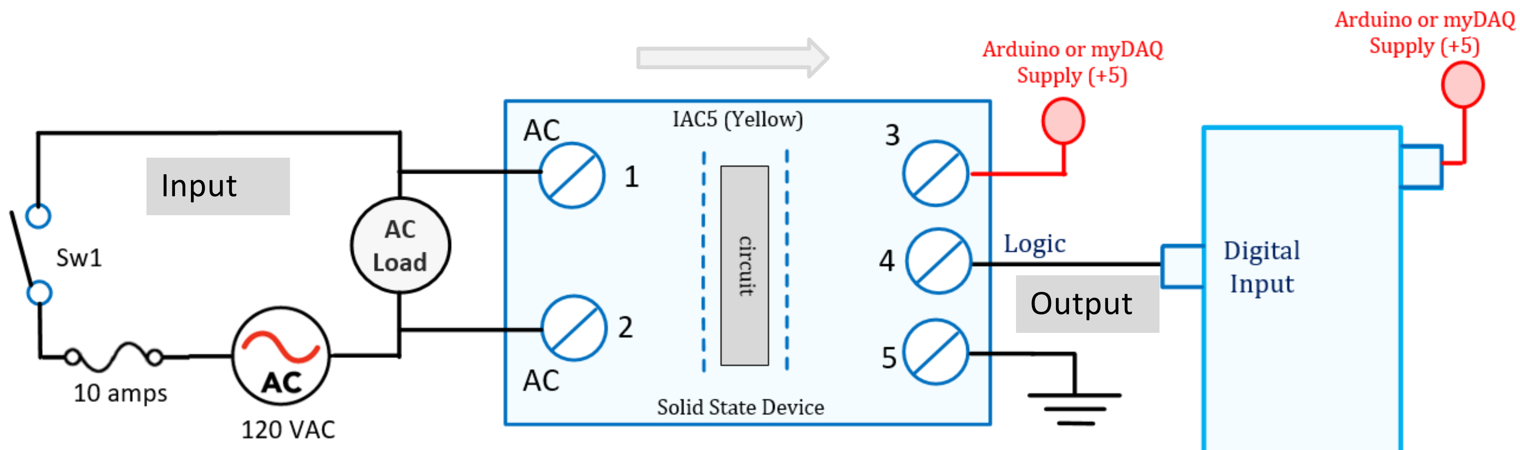
OAC5 (most common)– Controls an AC signal using logic levels. Current flowing through the LED energized a photo transistor. A triac is energized using a zero voltage detection circuit. The zero detection circuits used to energize the device only while the current is low, this helps to reduce spikes when turning the device on or off. The output has a snubber circuit to prevent damage from inductive devices.

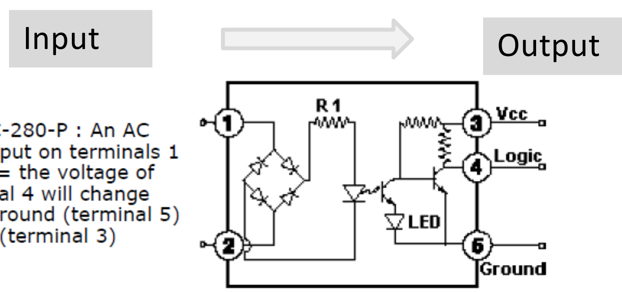




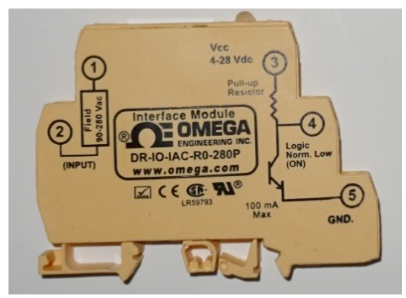


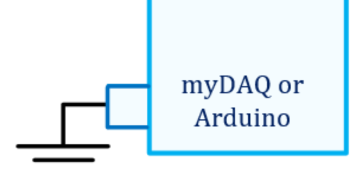
IAC5 – Measures an AC input voltage and converts it to a logic level. The AC is converted to DC using a bridge rectifier. The DC current activates an led which then turns on an LED and transistor causing the logic level to change.



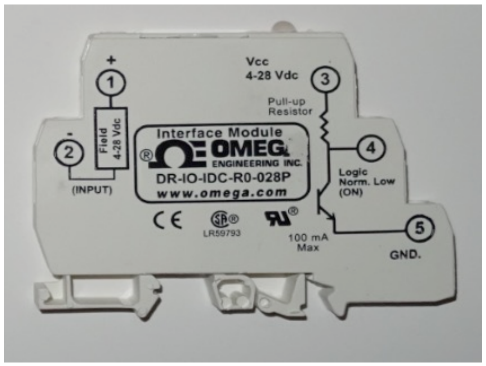


IO-IAC-280-P : An AC field input on terminals 1 and 2 = the voltage of terminal 4 will change from ground (terminal 5) to vcc (terminal 3)



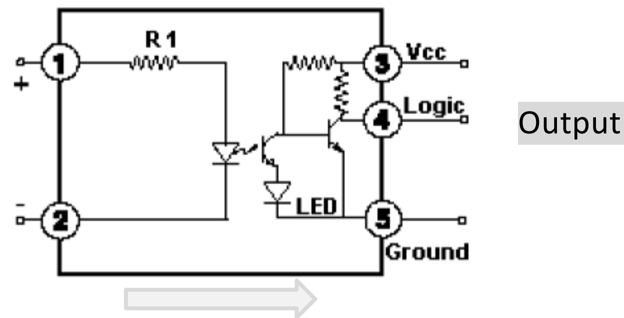


IDC5 – Measures an DC input voltage and converts it to a logic level.



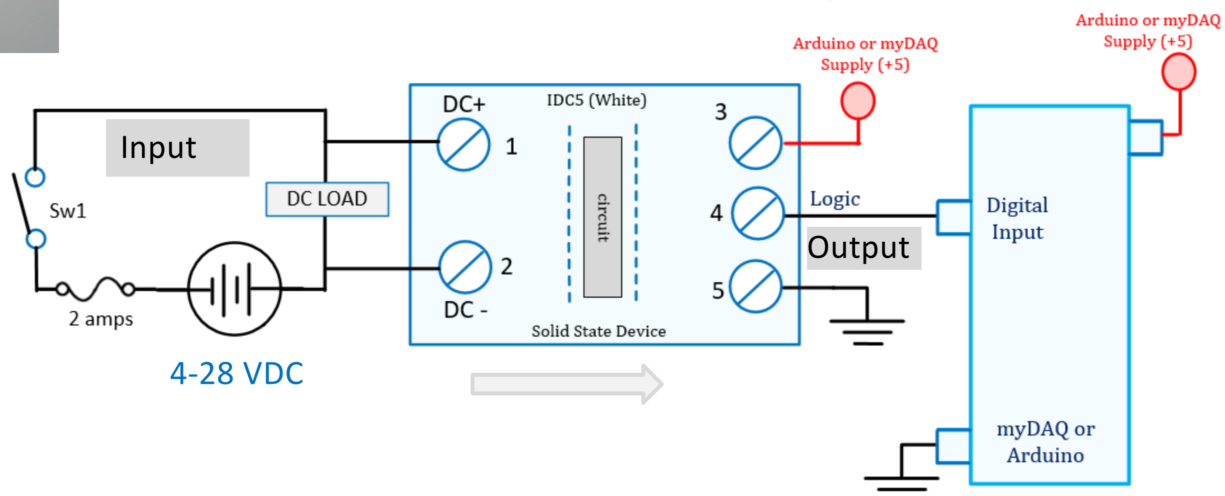
IO-IDC-028-P : A DC field input on terminals 1 and 2 = the voltage of terminal 4 will change from ground (terminal 5) to vcc (terminal 3)

Input

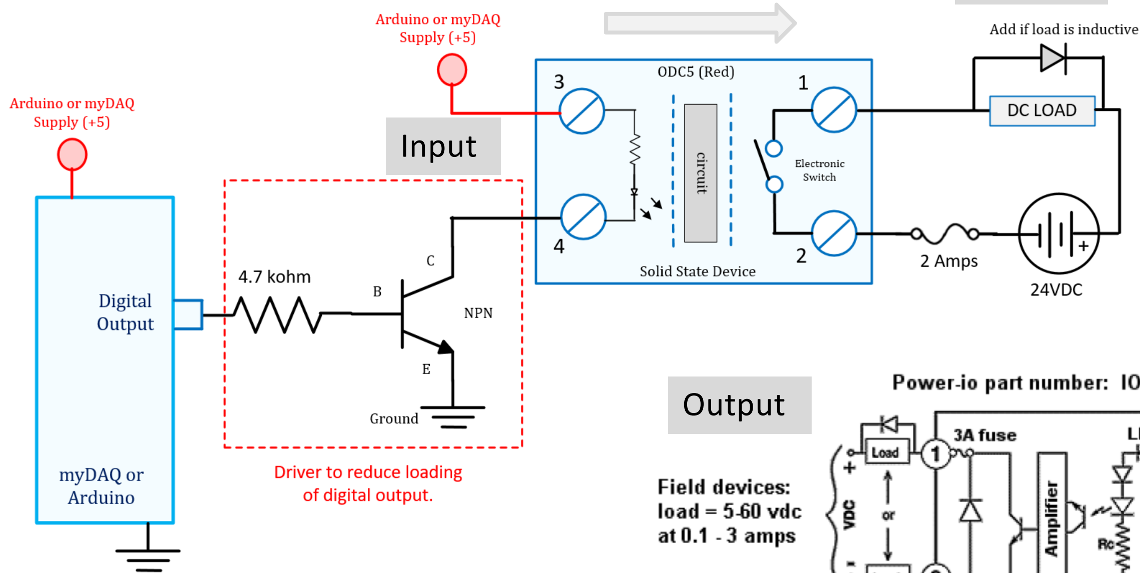


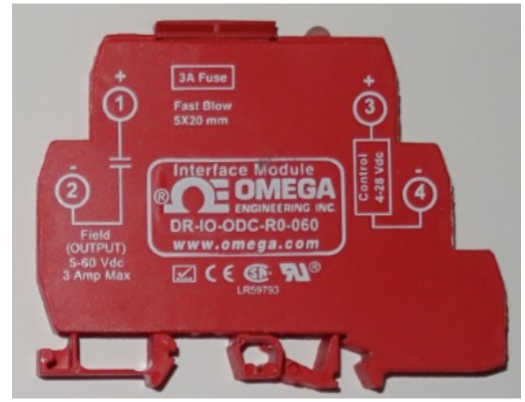
IDC5

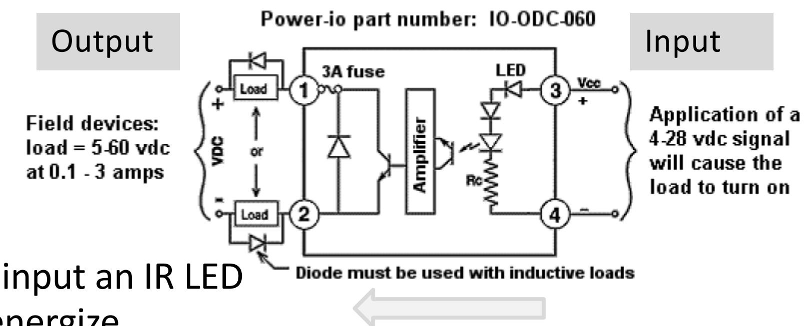
This module is used to determine the state of a DC load. With a value between 4 to 28 VDC the module output will be a logic high.



ODC5 – uses a logic signal to controls a DC voltage. The transistor driver is added to reduce the load on the output pin of the controller. The diode across the load is a flyback diode which will reduce the spike created when an inductive load is turned off.







ODC5 – when a DC voltage is applied to the input an IR LED turns on a transistor causing the output to energize.

AD623 Instrumentation Amplifier

The AD623 is an instrumentation amplifier. The gain of the amplifier is easily configured using one resistor. An output offset can also be easily added with a reference input pin. The device can be used to amplify signals from load cells, pressure sensors and thermocouple. The device has rail to rail output meaning the output signal can go from min supply to maximum supply.

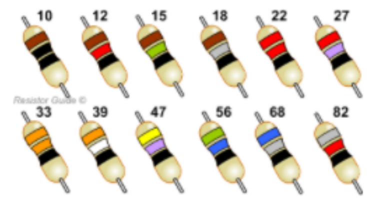
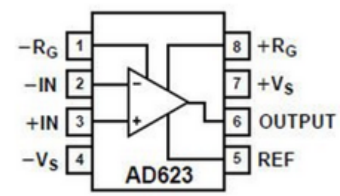


Table I. Required Values of Gain Resistors

Desired Gain	1% Std Table Value of R_G, Ω	Calculated Gain Using 1% Resistors
2	100 k	2
5	24.9 k	5.02
10	11 k	10.09
20	5.23 k	20.12
33	3.09 k	33.36
40	2.55 k	40.21
50	2.05 k	49.78
65	1.58 k	64.29
100	1.02 k	99.04
200	499	201.4
500	200	501
1000	100	1001

AD623 Data Sheet info

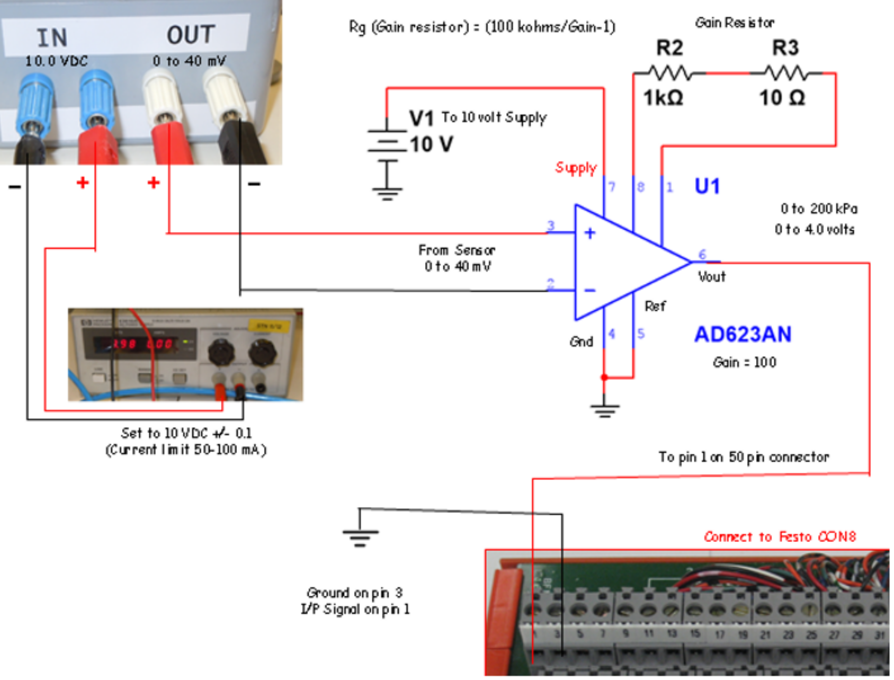


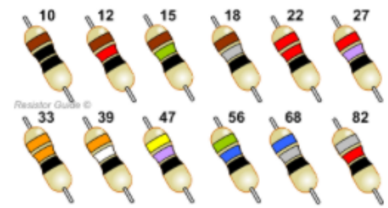
$$R_G = 100\ k\Omega/(G - 1)$$

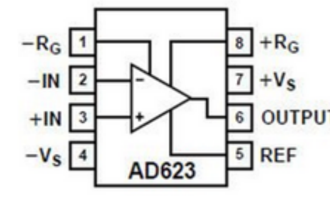
$$G = (100k\Omega\ /R_G)+1$$

AD623 Instrumentation Amplifier

0 – 200 kPa differential Pressure produces an output of 0 to 40 mV.







The output from the sensor is 0 to 40 mV. This is too low for the A/D converter of the Arduino or the myDAQ. The amplifier will increase the voltage by a factor of 100 using the instrumentation amplifier. The output will have a range of 0 to 4 volts for a pressure of 0 to 200 kPa.

Type "K" (yellow) Thermocouple

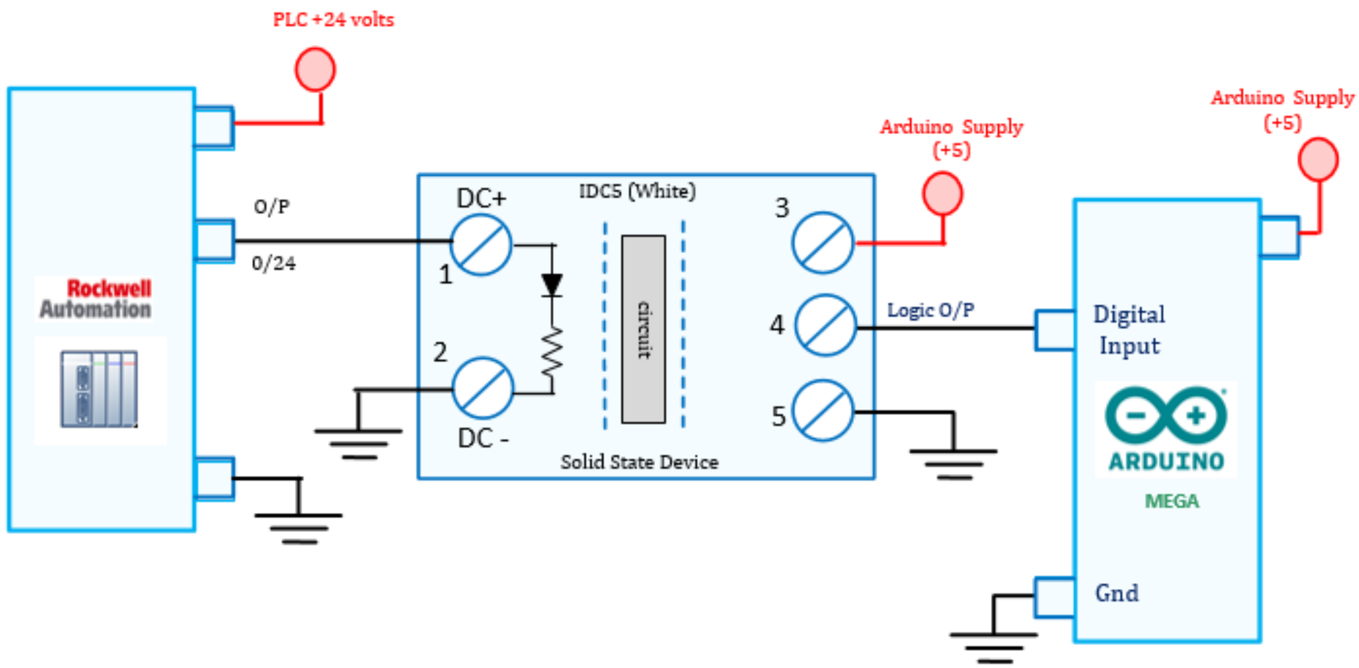
TABLE 9 ***Type K Thermocouple*** — *thermoelectric voltage as a function of temperature (°C); reference junctions at 0 °C*

K °C

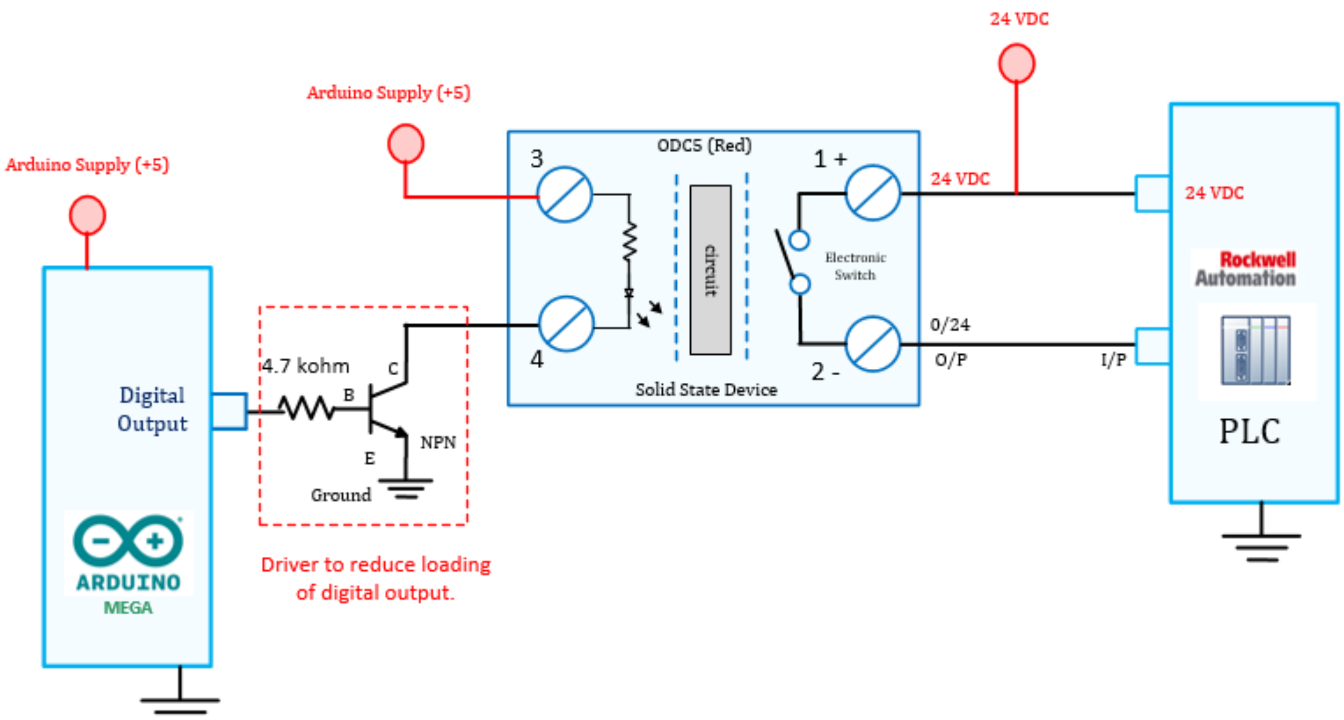
°C	0	1	2	3	4	5	6	7	8	9	10	°C
					Thermoelectric Voltage in Millivolts							
-30	-1.156	-1.194	-1.231	-1.268	-1.305	-1.343	-1.380	-1.417	-1.453	-1.490	-1.527	-30
-20	-0.778	-0.816	-0.854	-0.892	-0.930	-0.968	-1.006	-1.043	-1.081	-1.119	-1.156	-20
-10	-0.392	-0.431	-0.470	-0.508	-0.547	-0.586	-0.624	-0.663	-0.701	-0.739	-0.778	-10
0	0.000	-0.039	-0.079	-0.118	-0.157	-0.197	-0.236	-0.275	-0.314	-0.353	-0.392	0
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798	10
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.163	1.203	20
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612	30
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	40
50	2.023	2.064	2.106	2.147	2.188	2.230	2.271	2.312	2.354	2.395	2.436	50
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851	60
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267	70
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	80
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096	90

About 40 uVolts /degree Celsius Type K

Solid State (PLC to Arduino)

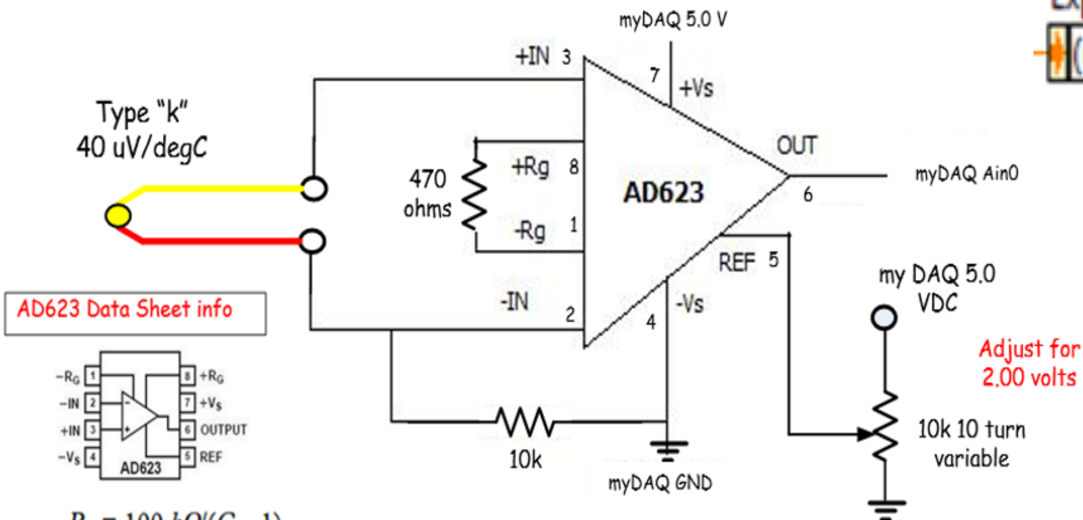


Solid State Relay (Logic to PLC)



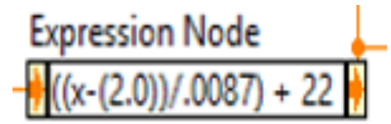
Solid State Relay

Arduino or myDAQ T/C Amplifier



$R_G = 100\ k\Omega/(G - 1)$

$G = (100k\Omega\ /R_G)+1$

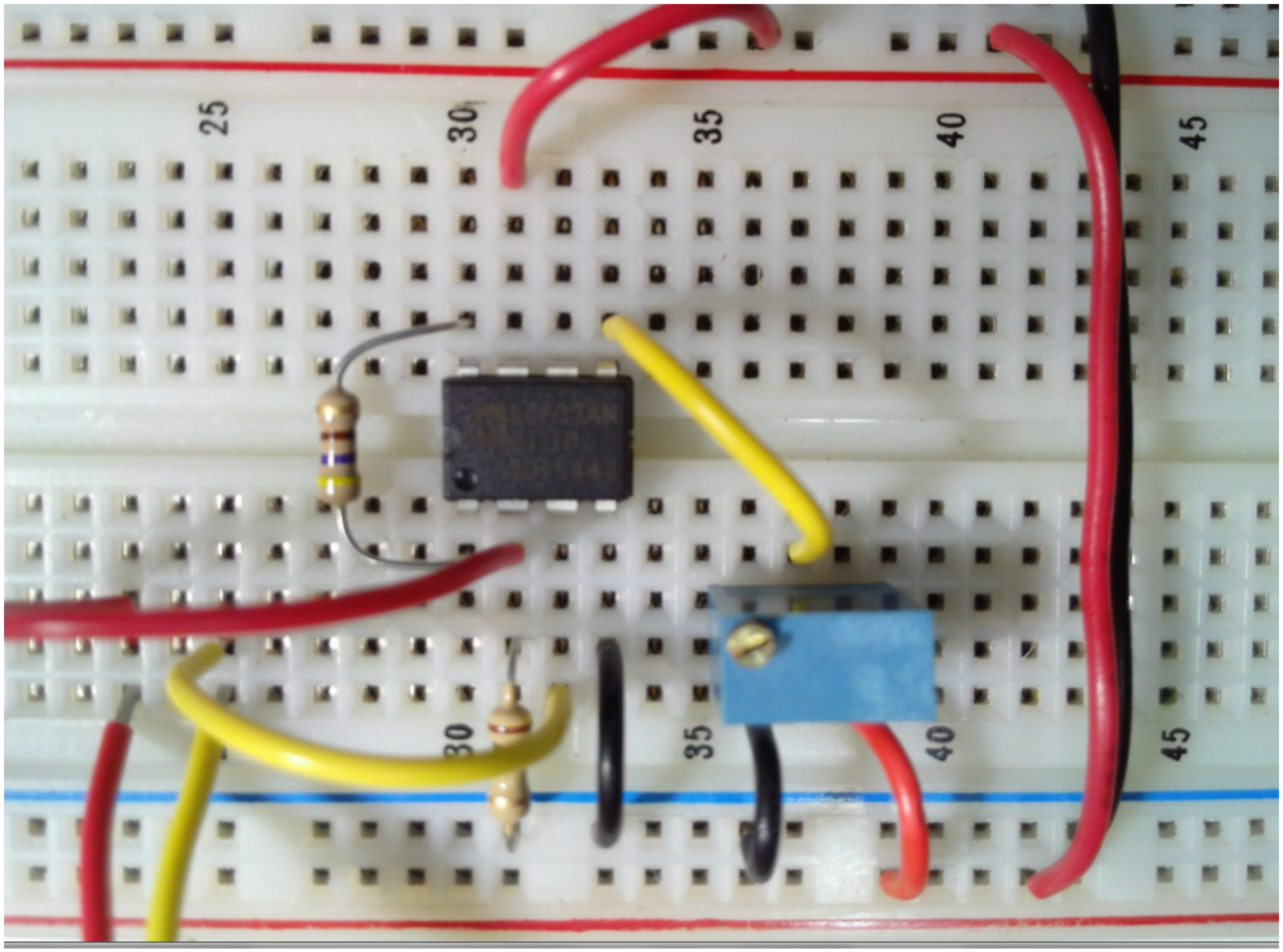


The AD623 is an instrumentation amplifier. The gain of the amplifier is easily configured using one resistor. An output offset can also be easily added with a reference on pin 5.

The gain resistor is placed between pins 1 and 8. The output is on pin 6.

In this example the gain =
Gain = (100kohm/470)+1
= 214

214 * 41uV = 0.0087 volts.
Assume CJ = 22 degC
Assume offset = 2.0 volts.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Configurable Transducers

JUMPFLEX® Transducers

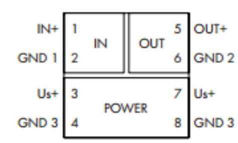
Isolation amplifier, with zero/span adjustment

Short description:
The configurable 857-400 Isolation Amplifier is used to convert, amplify, filter and electrically isolate analog standard signals.

Characteristics:
- Zero/span adjustment across the entire measuring range
- Calibrated scale switching
- Switchable max. operating frequency
- Safe 3-way isolation with 2.5kV test voltage to EN 61140

Configuration via:

DIP Switches



Transducer Specs

WAGO

Technical Data

Configuration:	
Configuration	DIP switches
Input:	
Input signal	0 ... 20 mA, 4 ... 20 mA,
	0... 5 V, 0 ... 10 V, 2 ... 10 V, 1 ... 5 V
	(calibrated switchable)
Input resistance	≤ 50 Ω (In = mA)
	≥ 100 kΩ (In = V)
Output:	
Output signal	0 ... 20 mA, 4 ... 20 mA,
	0... 5 V, 0 ... 10 V, 2 ... 10 V, 1 ... 5 V
	(calibrated switchable)
Load impedance	600 Ω (Out = mA)
	2 kΩ (Out = V)
General specifications:	
Voltage supply V_s	24V DC
Supply voltage range	16.8 V ... 31.2 V
Current consumption at 24 V DC	≤ 25 mA
Max. operating frequency	100 Hz / 5 kHz
	(switchable via DIP switch)
Response time ($T_{10\text{-}90}$)	< 3.5 ms / < 100 µs
Transmission error	≤ 0.1 % of the full scale value
Temperature coefficient	≤ 0.01 % /K
Zero/span adjustment	± 3% of upper range value

A transducer converts one signal form to another.

Examples:

Resistance to voltage: 0-100 ohms to 0- 10 volts.
Voltage to current: 0-10 to 4-20 mA.
Current to Voltage: 4 to 20 mA to 0 to 5 volts.

Display and keypad configuration.

Suitable for 12.5 mm and
22.5 wide housing

Item No. 2857-900

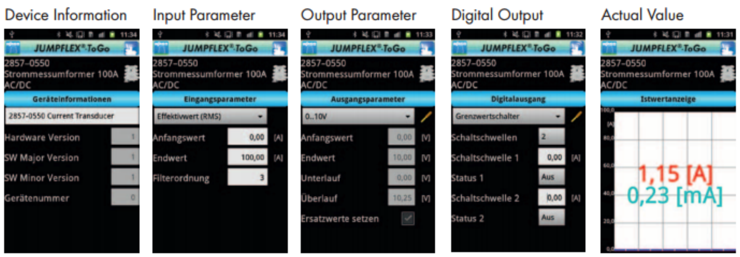
Some devices can easily be configured using an LCD display and a basic keypad.

They include a built in controller for configuration.

Most of these modules fit onto an industrial DIN rail.

JUMPFLEX®-ToGo Configuration App – DIP Switch Alternative

The free "*JUMPFLEX®-ToGo*" app brings the power of a PC-based configuration software to your mobile device. Configure 857 Series transducers' input and output parameters via finger swipe on your Android-based smartphone or tablet. Furthermore, both configuration data and actual measured values can be easily displayed. The WAGO 750-921 *Bluetooth®* Adapter communicates between your smartphone and the transducer.



QR Code

(Android-based)

21

WAGO – JUMPFLEX configuration.

Smart phone configuration using a Bluetooth adapter.

Now I have a reason for using my $800.00 smartphone!

Dip Switch S1 (2-fold)			Dip Switch S2 (6-fold)							
Input Signal			Output Signal						Max. Operating Frequency	
1	2		1	2	3	4	5		6	
•		0 ... 20 mA						0 ... 20 mA		5 kHz
						•		4 ... 20 mA	•	100 Hz
			•	•				0 ... 10 V		
			•	•		•		2 ... 10 V		
			•	•	•			0 ... 5 V		
			•	•	•	•		1 ... 5 V		
•		4 ... 20 mA					•	0 ... 20 mA		
								4 ... 20 mA		
			•	•			•	0 ... 10 V		
			•	•				2 ... 10 V		
			•	•	•		•	0 ... 5 V		
			•	•	•			1 ... 5 V		
	•	0 ... 10 V						0 ... 20 mA		
						•		4 ... 20 mA		
			•	•				0 ... 10 V		
			•	•		•		2 ... 10 V		
			•	•	•			0 ... 5 V		
			•	•	•	•		1 ... 5 V		
	•	2 ... 10 V					•	0 ... 20 mA		
								4 ... 20 mA		
			•	•			•	0 ... 10 V		
			•	•				2 ... 10 V		
			•	•	•		•	0 ... 5 V		
			•	•	•			1 ... 5 V		
		0 ... 5 V						0 ... 20 mA		
						•		4 ... 20 mA		
			•	•				0 ... 10 V		
			•	•		•		2 ... 10 V		
			•	•	•			0 ... 5 V		
			•	•	•	•		1 ... 5 V		
		1 ... 5 V					•	0 ... 20 mA		
								4 ... 20 mA		
			•	•			•	0 ... 10 V		
			•	•				2 ... 10 V		
			•	•	•		•	0 ... 5 V		
			•	•	•			1 ... 5 V		

JUMPFLEX® Transducers

Isolation amplifier, with zero/span adjustment

A set of jumpers are used to select the input and output signal range. Examples:

0-20 mA

4-20 mA

0 – 10 VDC

2-10 VDC

0-5 VDC

1-5 VDC

Omega T/C Transducer

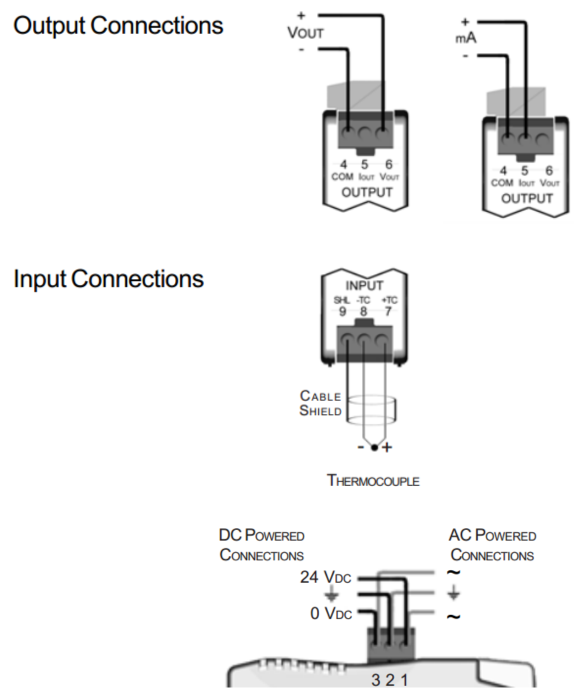
This converter is powered by
24 VDC.

The input can be a type "K", "T" or "J" thermocouple selected using jumpers.

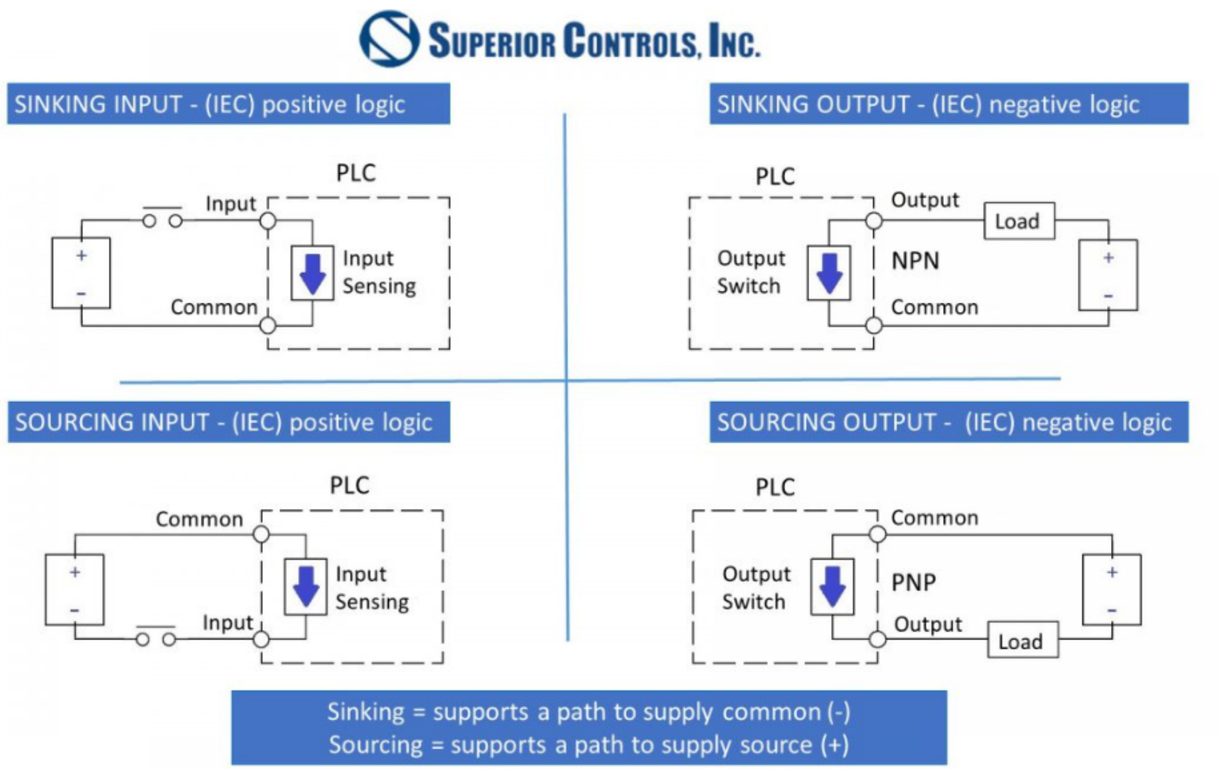
The device includes cold junction compensation.

The output is jumper selectable for 4 to 20 mA or 0 to 10 volts.

The device is calibrated using zero and span adjustments.



Sink and Source Examples



An electromechanical relay is robust and versatile. However, it takes up more room and is slower than an SSR. Typically, an EMR needs 5 to 15 ms to switch and settle—a delay which is not acceptable in some applications. Moreover, due to their moving parts, EMRs have a shorter operational lifetime.

An electromechanical relay uses magnetic fields to provide isolation; an SSR, in contrast, achieves this goal generally through opto-coupling. As shown in Figure 2, in an SSR a small input voltage, typically 3 to 32 VDC, is used to illuminate an LED. When the LED is turned on, an output photo-sensitive device, such as a TRIAC, turns on and conducts current.

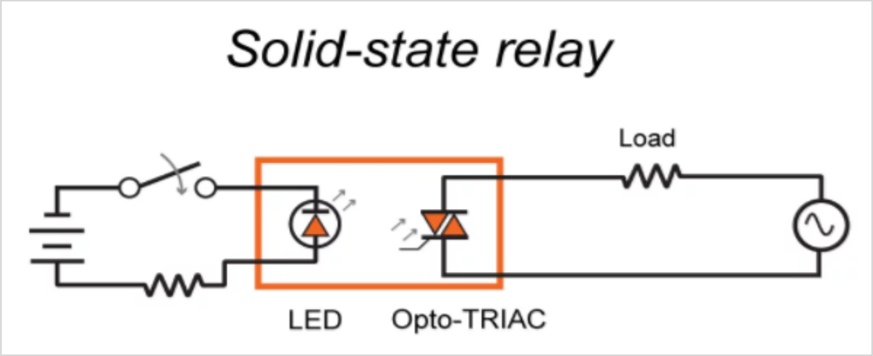
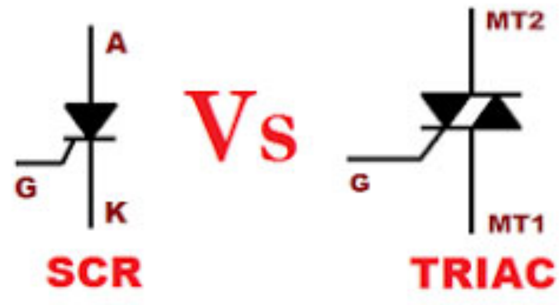


Figure 2. *The basic structure of an SSR. Image adapted from pc-control.*

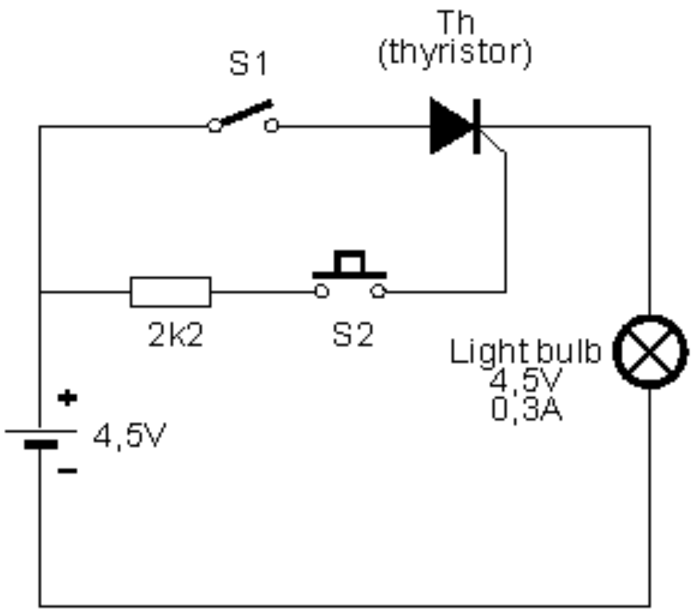
An SSR can be designed to switch a DC or an AC load, and some types are capable of switching both AC and DC loads. An SSR's output type (AC, DC, or AC/DC) is determined by the type of switching device: a transistor (either bipolar or MOS), an SCR, or a TRIAC.

SCR	TRIAC
SCR stands for silicon controlled rectifier.	**TRIAC** stands for triode for alternating current.
The SCR is unidirectional device.	The TRIAC is bidirectional device.
It available in large ratings.	It available in smaller ratings.
The SCR control DC power.	The TRIAC control DC as well as AC power.
The SCR can be triggered by positive gate voltage only.	The TRIAC can be triggered either by positive or negative gate voltage.
In SCR only one mode of operation is possible.	In TRIAC four different modes of operation is possible.
It is more reliable.	It is less reliable.
The SCR conduct current in one direction only.	The TRIAC conduct current in both the directions.
It needs two heat sink.	It needs only one heat sink.

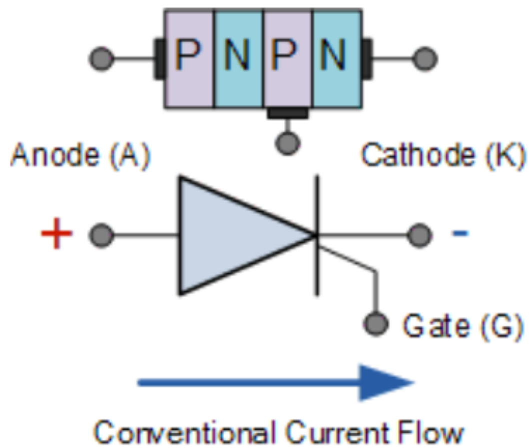


SCR Vs TRIAC

Difference between SCR and TRIAC



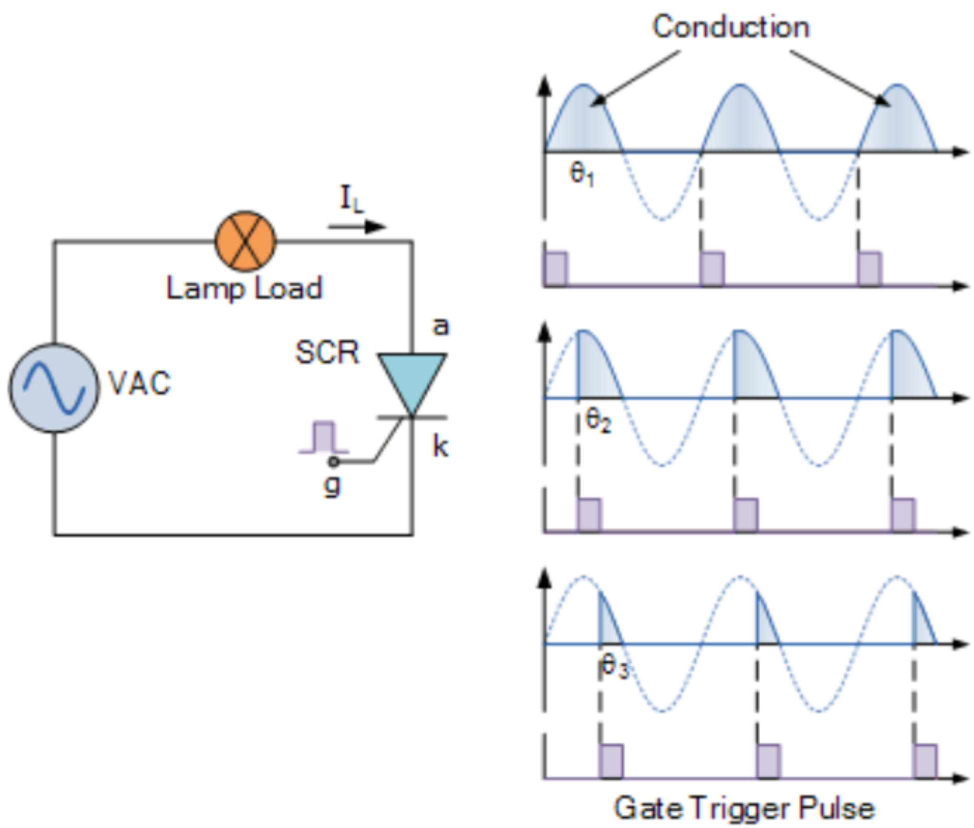
Thyristor I-V Characteristics Curves



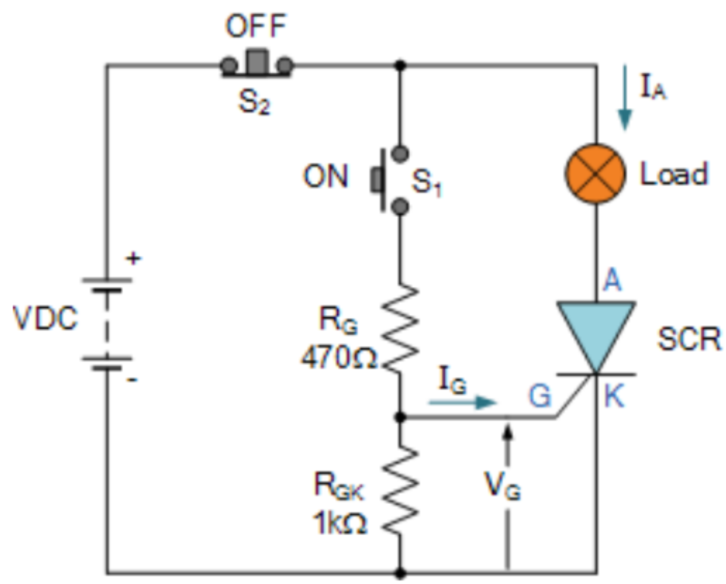
Static Characteristics of a Thyristor

- Thyristors are semiconductor devices that can operate only in the switching mode.
- Thyristor are current operated devices, a small Gate current controls a larger Anode current.
- Conducts current only when forward biased and triggering current applied to the Gate.
- The thyristor acts like a rectifying diode once it is triggered “ON”.
- Anode current must be greater than holding current to maintain conduction.
- Blocks current flow when reverse biased, no matter if Gate current is applied.
- Once triggered “ON”, will be latched “ON” conducting even when a gate current is no longer applied providing Anode current is above latching current.

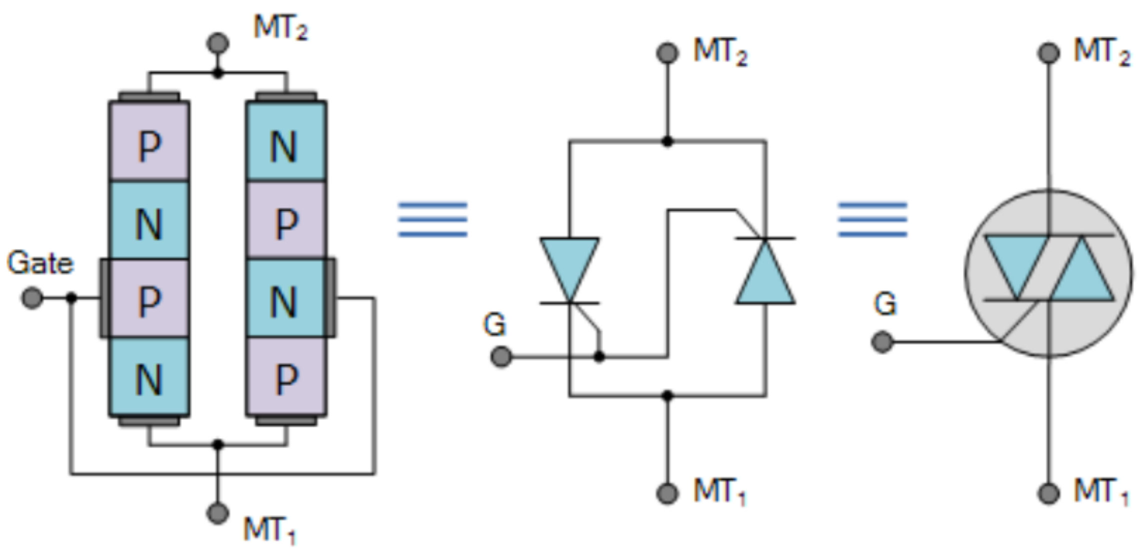
Thyristor Phase Control



DC Thyristor Switching Circuit



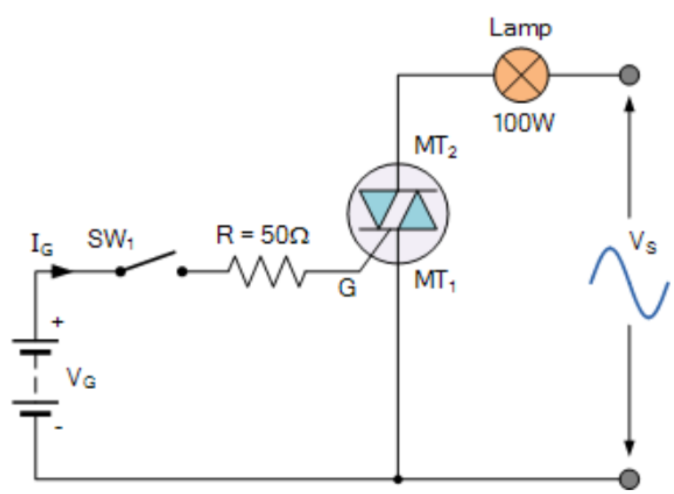
Triac Symbol and Construction



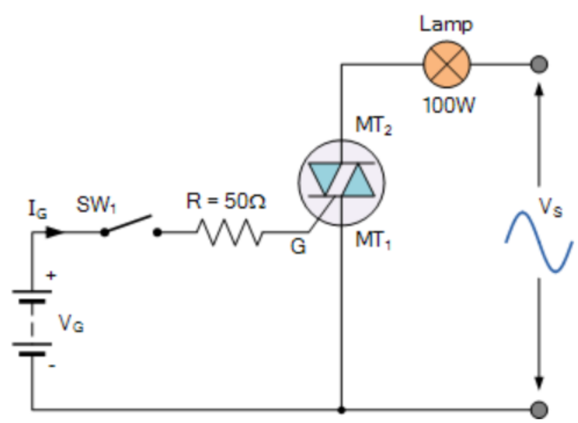
Physical Construction Two-Thyristor Analogy Circuit Symbol

The **Triac** is most commonly used semiconductor device for switching and power control of AC systems as the triac can be switched "ON" by either a positive or negative Gate pulse, regardless of the polarity of the AC supply at that time. This makes the triac ideal to control a lamp or AC motor load with a very basic triac switching circuit given below.

Triac Switching Circuit

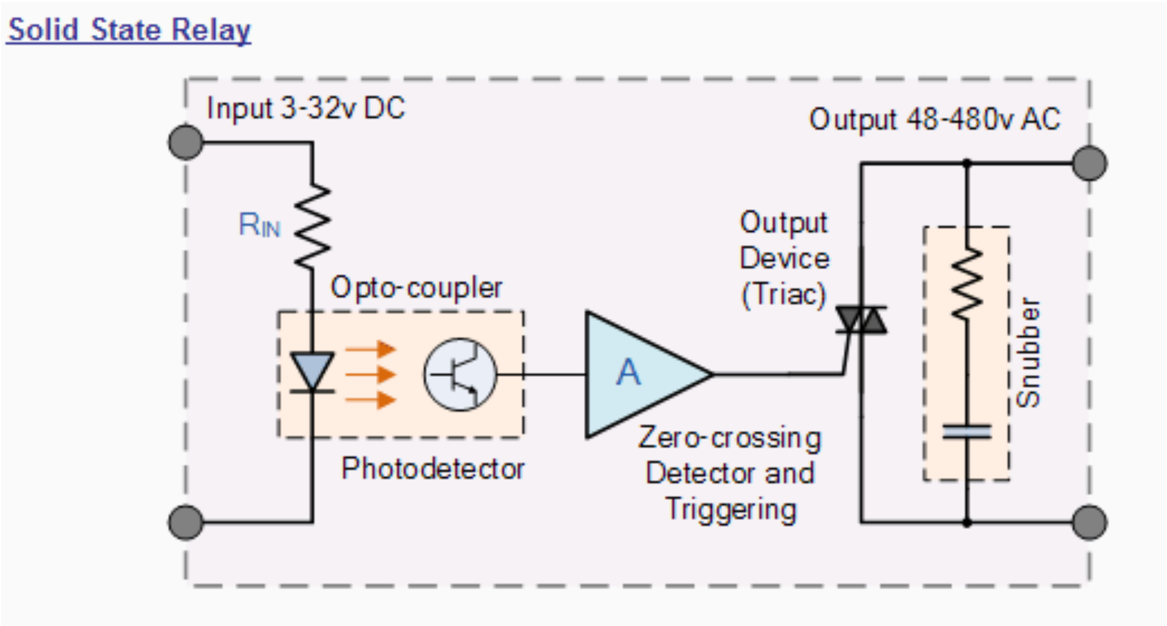


Triac Switching Circuit



The circuit above shows a simple DC triggered triac power switching circuit. With switch SW1 open, no current flows into the Gate of the triac and the lamp is therefore “OFF”. When SW1 is closed, Gate current is applied to the triac from the battery supply V_G via resistor R and the triac is driven into full conduction acting like a closed switch and full power is drawn by the lamp from the sinusoidal supply.

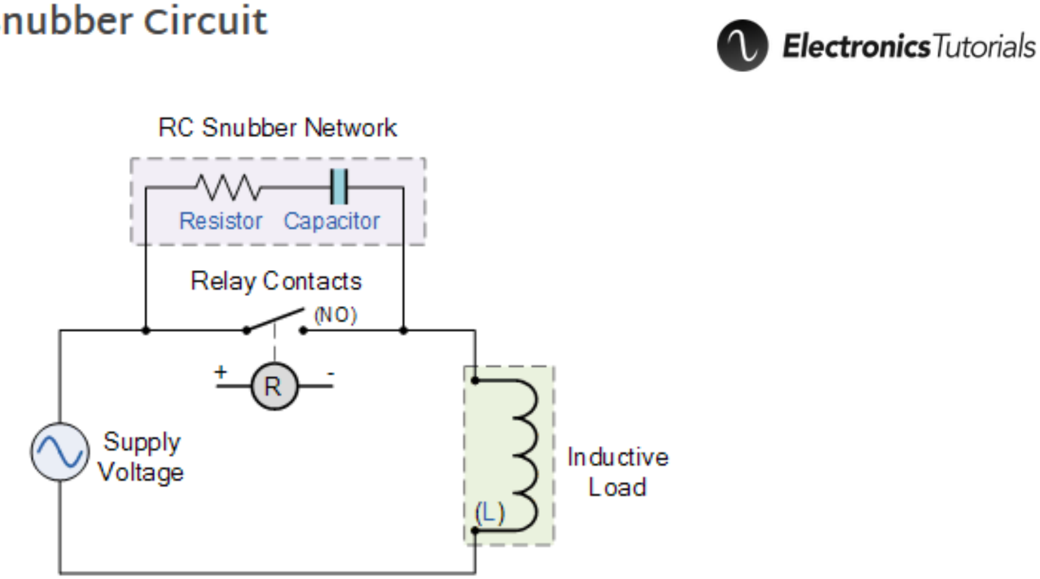
Inside a Solid State Relay (OAC5) Black



The solid state relay includes opto-isolation, a zero crossing detector, a triac and a snubber circuit to suppress transients from inductive loads. The zero crossing detector is used to turn on the load at the time the current is the lowest when using AC loads.

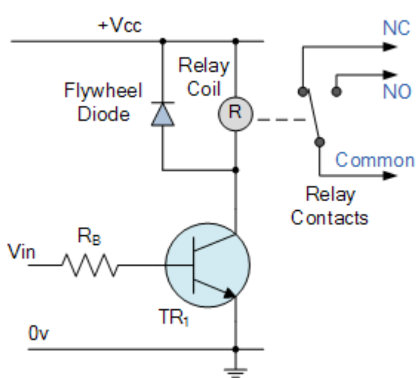
Extending the life of relay tips by reducing the amount of arcing generated as they open is achieved by connecting a Resistor–Capacitor network called an **RC Snubber Network** electrically in parallel with an electrical relay contact tips. The voltage peak, which occurs at the instant the contacts open, will be safely short circuited by the RC network, thus suppressing any arc generated at the contact tips. For example.

Electrical Relay Snubber Circuit



One of the more important parts of any electrical relay is its coil. This converts electrical current into an electromagnetic flux which is used to mechanically operate the relays contacts. The main problem with relay coils is that they are "highly inductive loads" as they are made from coils of wire. Any coil of wire has an impedance value made up of resistance (R) and inductance (L) in series (LR Series Circuit).

As the current flows through the coil a self induced magnetic field is generated around it. When the current in the coil is turned "OFF", a large back emf (electromotive force) voltage is produced as the magnetic flux collapses within the coil (transformer theory). This induced reverse voltage value may be very high in comparison to the switching voltage, and may damage any semiconductor device such as a transistor, FET or micro-controller used to operate the relay coil.



One way of preventing damage to the transistor or any switching semiconductor device, is to connect a reverse biased diode across the relay coil.

When the current flowing through the coil is switched "OFF", an induced back emf is generated as the magnetic flux collapses in the coil.

This reverse voltage forward biases the diode which conducts and dissipates the stored energy preventing any damage to the semiconductor transistor.

When used in this type of application the diode is generally known as a **Flywheel Diode**, **Free-wheeling Diode** and even **Fly-back Diode**, but they all mean the same thing. Other types of inductive loads which require a flywheel diode for protection are solenoids, motors and inductive coils.

As well as using flywheel Diodes for protection of semiconductor components, other devices used for protection include **RC Snubber Networks**, **Metal Oxide Varistors** or **MOV** and **Zener Diodes**.

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