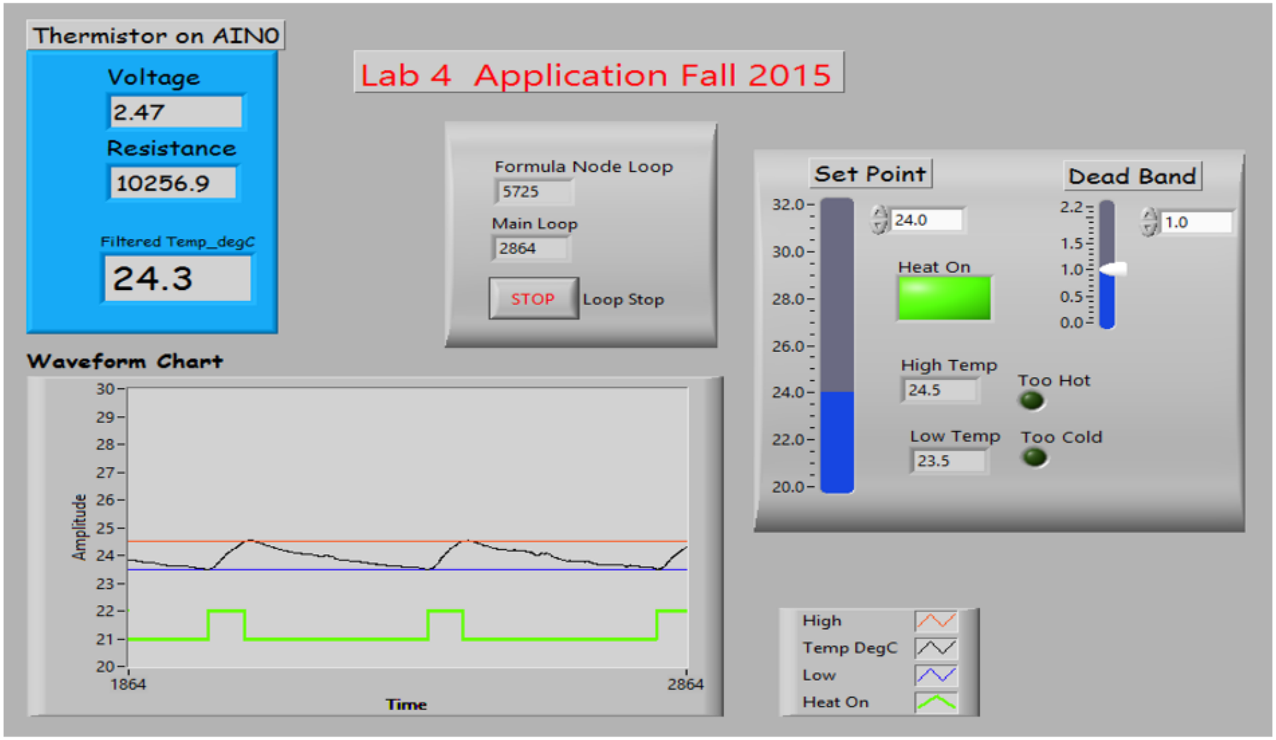
Week 6 Notes for Lab 4:

CAM8302E Fall 2018

Slide Index – Week 6

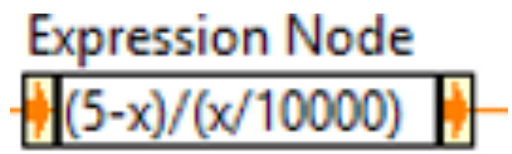


Lab 4 front panel: Chart indicates temperature, high and low limits and the state of the heater. The waveform is configured by right clicking on the chart and changing chart properties. The user configures the Set Point and Dead Band.

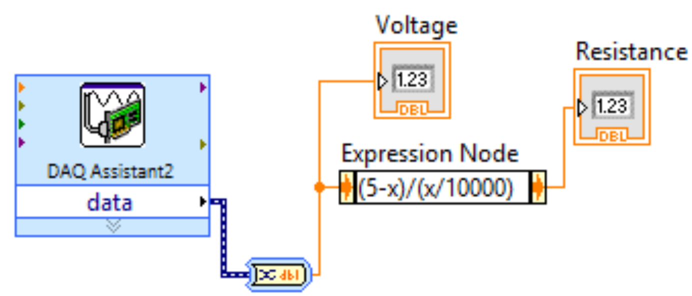
Thermistor Data and Conversion

10,0	19691
11,0	18788
12,0	17932
13,0	17120
14,0	16350
15,0	15618
16,0	14923
17,0	14236
18,0	13636
19,0	13040
20,0	12474
21,0	11928
22,0	11409
23,0	10915
24,0	10446
25,0	10000
26,0	9577,7
27,0	9175,6
28,0	8792,6
29,0	8427,7
30,0	8080,0
31,0	7748,5
32,0	7432,4
33,0	7131,0
34,0	6843,4
35,0	6569,0
36,0	6307,0
37,0	6057,0
38,0	5818,1
39,0	5590,0
40,0	5372,0

Data sheet for the thermistor comparing resistance to temperature.

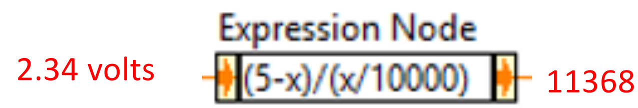


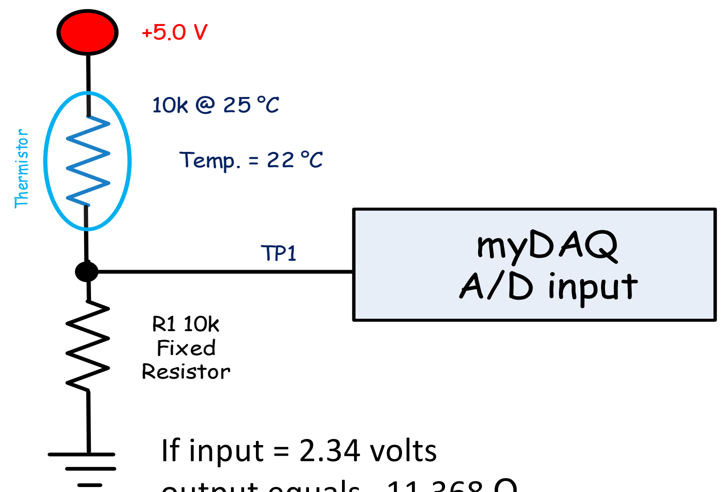
The expression node can be found under the numeric palette. It is used in a VI to create a simple math expression. The “x” represents the input value. The result of the expression is the output on the right. The input signal originates from the A/D converter. The dynamic data type from the DAQ assist is converted to a numeric scalar using a convert from DDT function. In this example the voltage from the thermistor voltage divider is converted to thermistor resistance.



Lab Thermistor Data

DegC	Resistance	DegC	Resistance
15,0	15618	26,0	9577,7
16,0	14923	27,0	9175,6
17,0	14236	28,0	8792,6
18,0	13636	29,0	8427,7
19,0	13040	30,0	8080,0
20,0	12474	31,0	7748,5
21,0	11928	32,0	7432,4
22,0	11409	33,0	7131,0
23,0	10915	34,0	6843,4
24,0	10446	35,0	6569,0
25,0	10000		

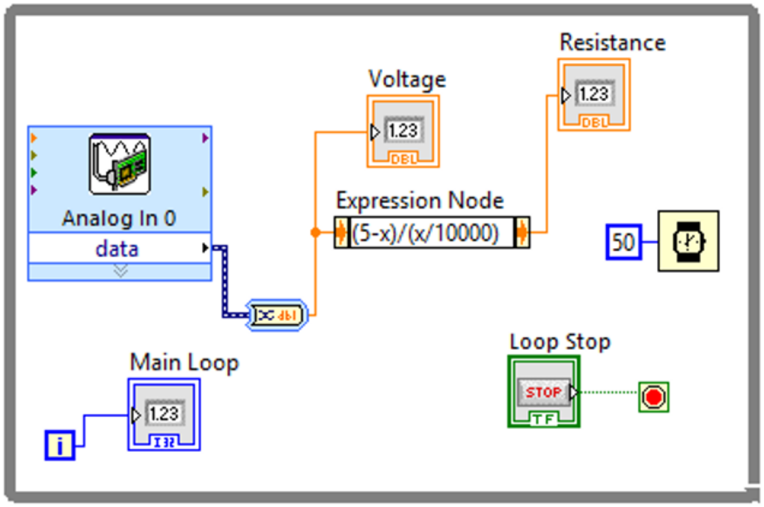


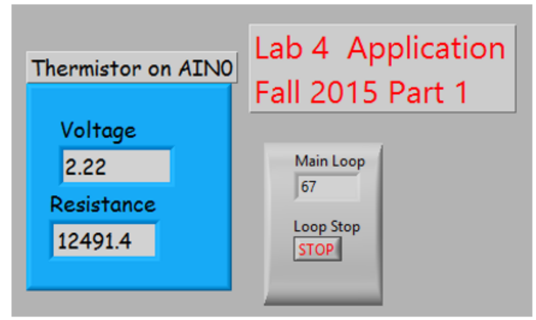


If input = 2.34 volts
output equals 11,368 Ω.

About 22 °C using the lookup chart.

Expression Example

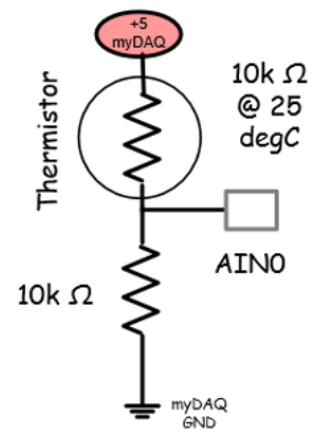


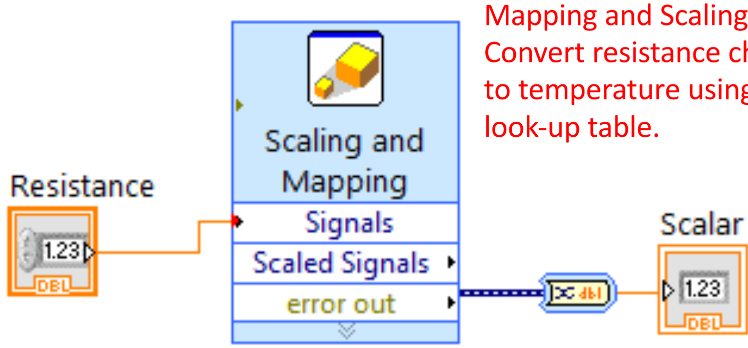


DegC	Resistance	DegC	Resistance
15,0	15618	26,0	9577,7
16,0	14923	27,0	9175,6
17,0	14236	28,0	8792,6
18,0	13636	29,0	8427,7
19,0	13040	30,0	8080,0
20,0	12474	31,0	7748,5
21,0	11928	32,0	7432,4
22,0	11409	33,0	7131,0
23,0	10915	34,0	6843,4
24,0	10446	35,0	6569,0
25,0	10000		

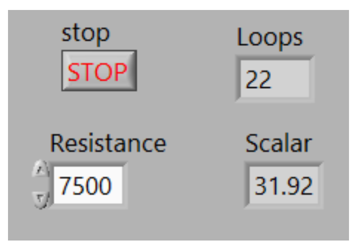
Lab Thermistor Data

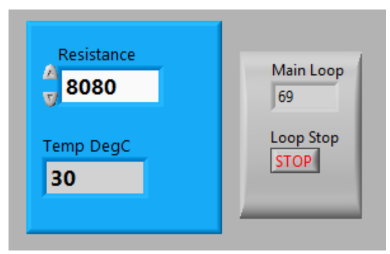
Complete VI with expression.





Mapping and Scaling – Convert resistance change to temperature using a look-up table.

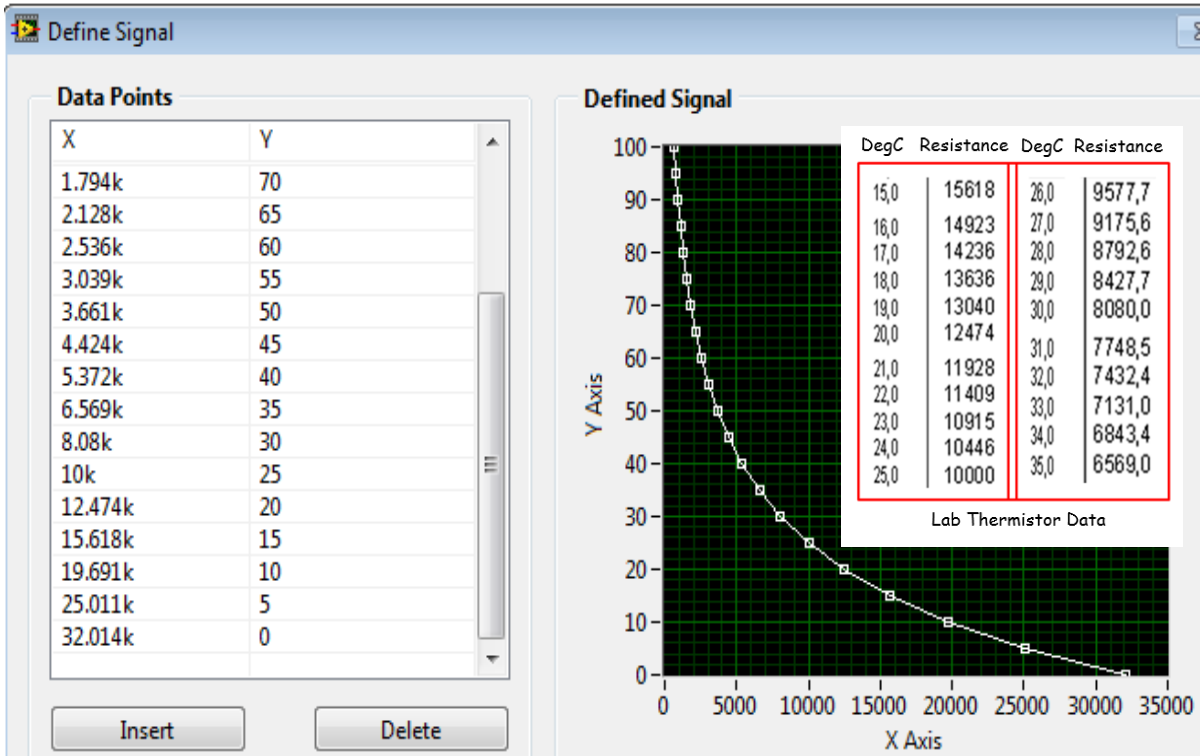


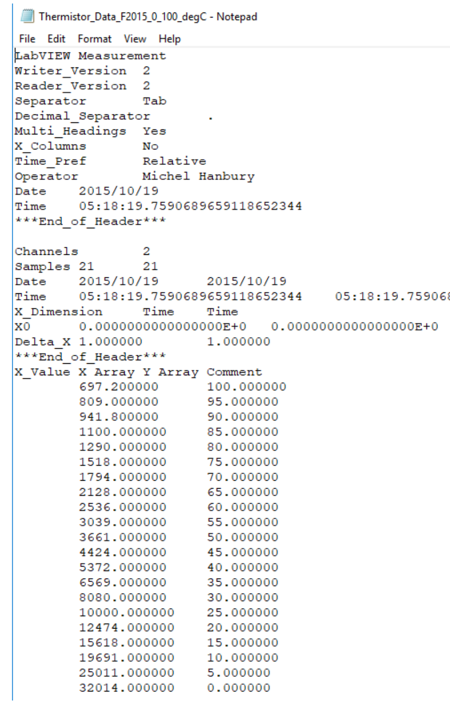


Data Points

X	Y
1.794k	70
2.128k	65
2.536k	60
3.039k	55
3.661k	50
4.424k	45
5.372k	40
6.569k	35
8.08k	30
10k	25
12.474k	20
15.618k	15
19.691k	10
25.011k	5
32.014k	0
Resistance	Temp degC

The input to the scaling and mapping function is the x value (the resistance) the output is the y value (the temperature). The function interpolates the values between the data points.





Thermistor_Data_F2015_0_100_degC - Notepad

File Edit Format View Help

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LabVIEW Measurement
Writer_Version  2
Reader_Version  2
Separator       Tab
Decimal_Separator       .
Multi_Headings  Yes
X_Columns       No
Time_Pref       Relative
Operator        Michel Hanbury
Date    2015/10/19
Time    05:18:19.7590689659118652344
***End_of_Header***

Channels        2
Samples 21      21
Date    2015/10/19      2015/10/19
Time    05:18:19.7590689659118652344    05:18:19.759068
X_Dimension     Time    Time
X0      0.0000000000000000E+0   0.0000000000000000E+0
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***End_of_Header***
X_Value X Array Y Array Comment
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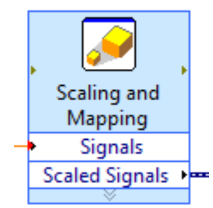
        809.000000      95.000000
        941.800000      90.000000
        1100.000000     85.000000
        1290.000000     80.000000
        1518.000000     75.000000
        1794.000000     70.000000
        2128.000000     65.000000
        2536.000000     60.000000
        3039.000000     55.000000
        3661.000000     50.000000
        4424.000000     45.000000
        5372.000000     40.000000
        6569.000000     35.000000
        8080.000000     30.000000
        10000.000000    25.000000
        12474.000000    20.000000
        15618.000000    15.000000
        19691.000000    10.000000
        25011.000000    5.000000
        32014.000000    0.000000
```



The chart is created using the thermistor data sheet. The x column represent the thermistor resistance. The Y-column the thermistor temperature.

Linear interpolation between two known points. Resistance is fairly linear between 30 to 35 degrees Celsius. Given a resistance value between 8080 ohms and 6569 ohms the temperature can be determined.

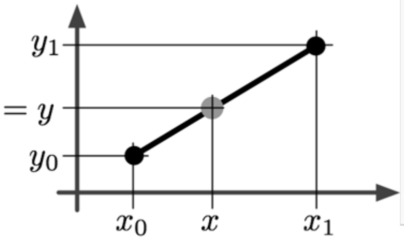
Solving this equation for *y*, which is the unknown value at *x*, gives

$$y = y_0 + (y_1 - y_0)\frac{x - x_0}{x_1 - x_0}$$

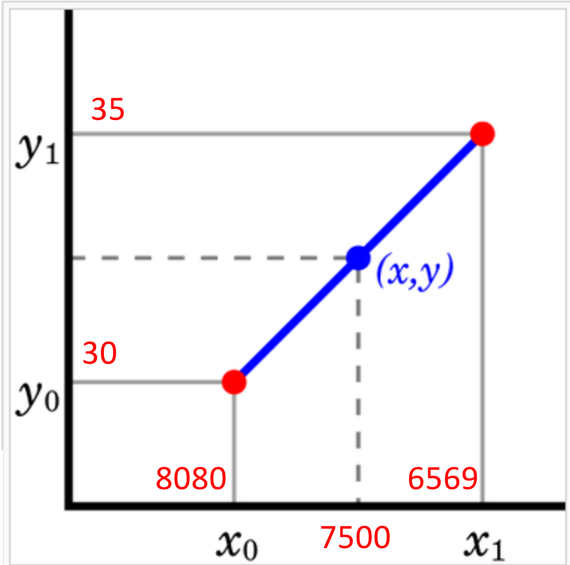
30   7500- 8080   35 - 30

$$y_0 + \frac{(x - x_0)(y_1 - y_0)}{x_1 - x_0} = y$$

6569- 8080

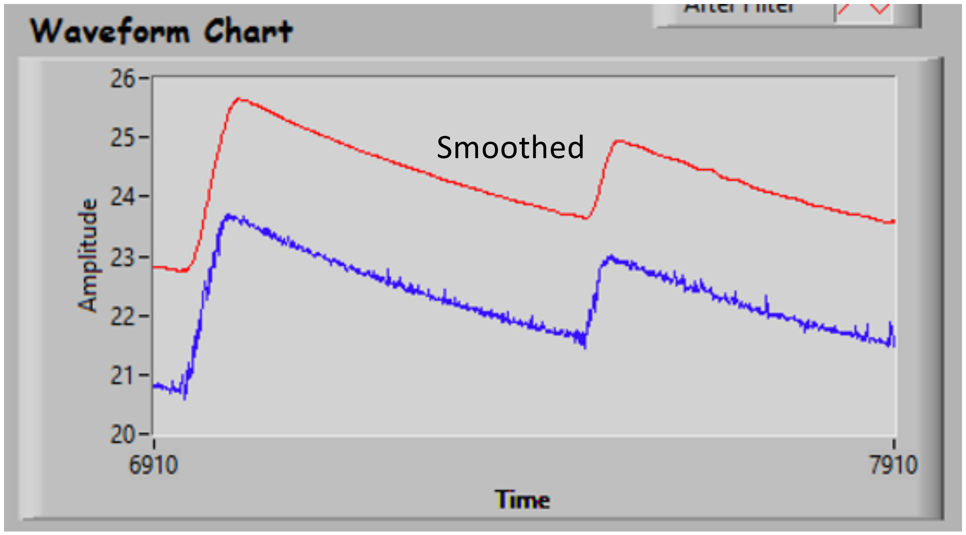


Y = 31.92



Given the two red points, the blue line is the linear interpolant between the points, and the value *y* at *x* may be found by linear interpolation.

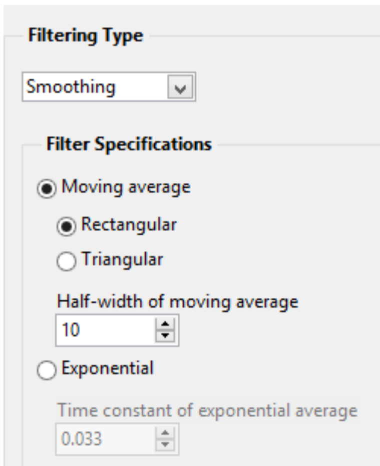
In this example the known resistance equals 7500 ohms (the x value). Using the formula above the value of the temperature can be calculated. In this example the answer is 31.9 degC.

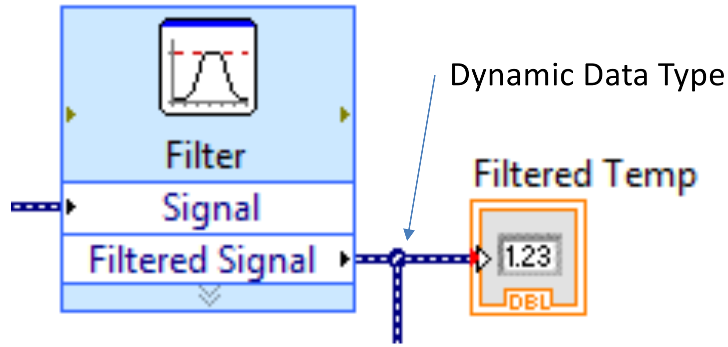


This chart is an example of a smoothing filter. The program uses a moving average filter to remove noise. The filter removes the noise from the A/D input signal and any electrical noise.

rectangular (default)—All samples in the moving-average window are weighted equally in computing each smoothed output sample.

Moving Average Filter

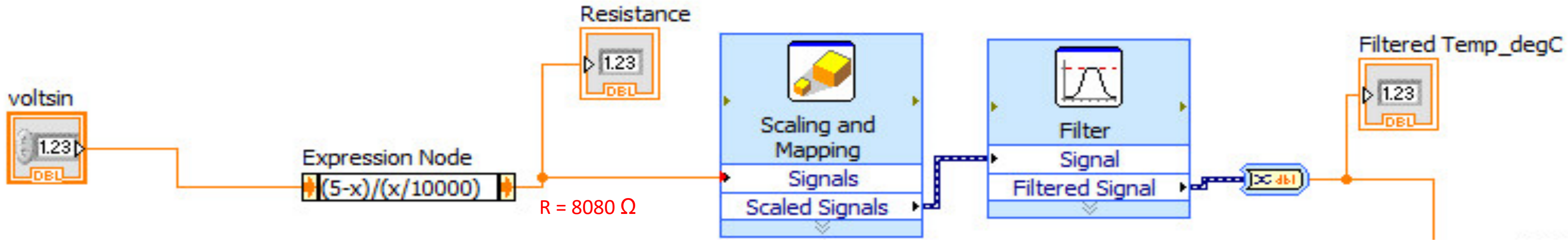




Express VI, Double Click to Configure

0	0	0	0	0									
	0	0	0	20	5								
		0	0	20	22	10.5							
			0	20	22	23	16.25						
				20	22	23	21	21.5					
					22	23	21	20	21.5				
						23	21	20	23	21.75			
							21	20	23	22	21.5		
								20	23	22	24	22.25	
									23	22	24	21	22.5

Assume 30 °C



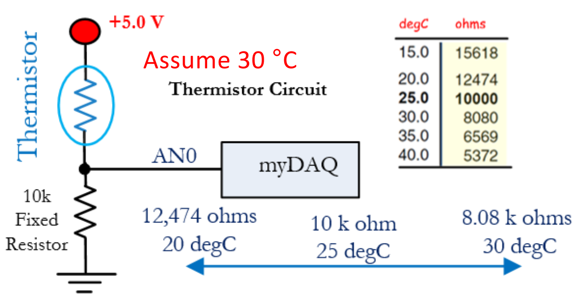
Read Voltage From Divider.

Convert to resistance

Convert to temperature

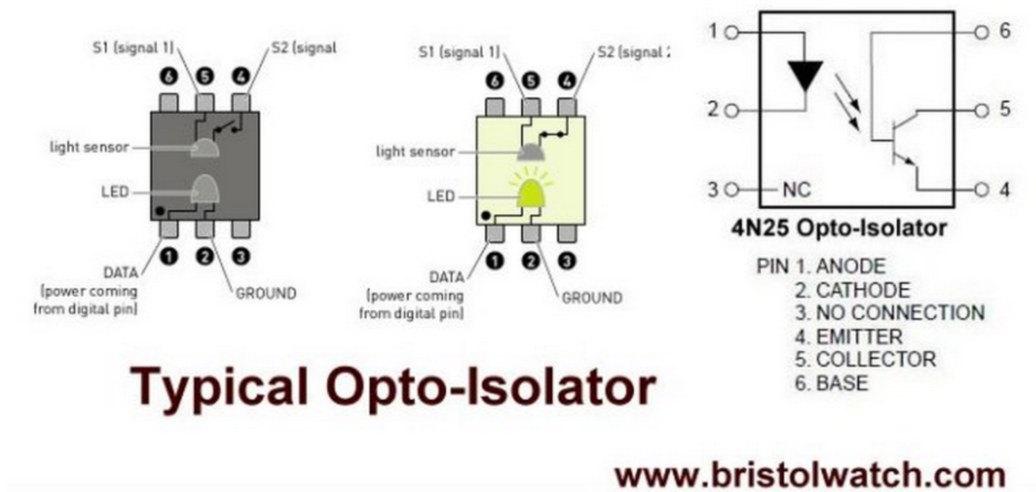
Smooth out the signal.

Send the value to the rest of the program.



degC	ohms
15.0	15618
20.0	12474
25.0	**10000**
30.0	8080
35.0	6569
40.0	5372

Signal Conversion Steps



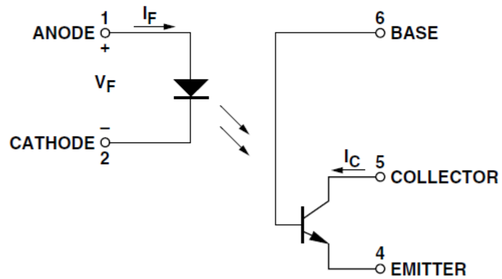
1. When current flows through the internal IR LED, light strikes the base of a photo sensitive transistor turning the transistor on, providing a path to ground between pins 4 and 5.

2. When no current flows the transistor is turned off, acting like an open circuit.

4N25 Opto-coupler

4N25M

Schematic



FAIRCHILD SEMICONDUCTOR®

Optocoupler Specification Definitions

Definitions

1. **CTR (current transfer ratio):** Ratio of the collector to the diode forward current I_C/I_F.
2. **I_F:** Current flowing through a diode from anode to cathode.
3. **BV_{CEO}:** Collector to emitter breakdown voltage with the collector open.
4. **BV_{CBO}:** Collector to base breakdown voltage with the emitter open.
5. **BV_{ECO}:** Emitter to collector breakdown voltage with the base open.
6. **$V_{CE(sat)}$:** Collector to emitter saturation voltage.
7. **t_{ON}/t_{OFF}:** Turn-on switching time; turn-off switching time.

Absolute Maximum Ratings

Storage Temperature, T_S	–55°C to +150°C
Operating Temperature, T_A	–55°C to +100°C
Lead Solder Temperature, max. (1.6 mm below seating plane)	260°C for 10 s
Average Forward Current, I_F	80 mA
Reverse Input Voltage, V_R	6 V
Input Power Dissipation, P_I	150 mW
Collector Current, I_C	100 mA
Collector-Emitter Voltage, V_{CEO}	30 V
Emitter-Collector Voltage, V_{ECO}	7 V
Collector-Base Voltage, V_{CBO}	70 V
Collector Power Dissipation	150 mW
Total Power Dissipation	250 mW
Isolation Voltage, V_{iso} (AC for 1 minute, R.H. = 40 ~ 60%)	2500 Vrms

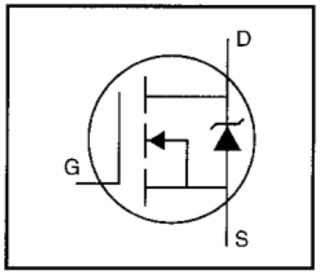
International
IOR Rectifier

PD-9.557C

IRLZ24

HEXFET® Power MOSFET

- Dynamic dv/dt Rating
- Logic-Level Gate Drive
- $R_{DS(on)}$ Specified at V_{GS}=4V & 5V
- 175°C Operating Temperature
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements



V_{DSS} = 60V

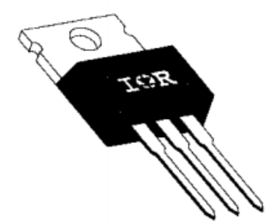
$R_{DS(on)}$ = 0.10Ω

I_D = 17A

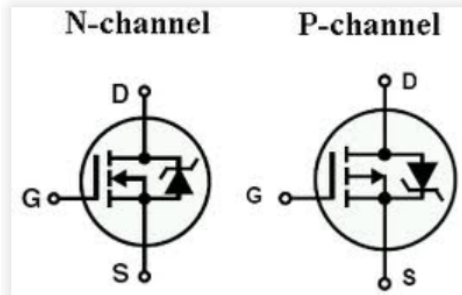
Description

Third Generation HEXFETs from International Rectifier provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



TO-220AB



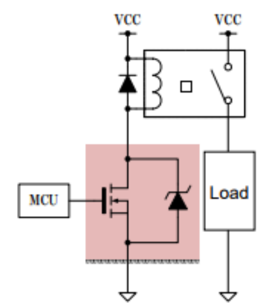
Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 5.0 V	17	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 5.0 V	12	
I_{DM}	Pulsed Drain Current ①	68	
P_D @ T_C = 25°C	Power Dissipation	60	W
	Linear Derating Factor	0.40	W/°C
V_{GS}	Gate-to-Source Voltage	±10	V

About Zener diode built in MOSFET

Avalanche failure

Avalanche failure may occur when MOSFET breaks down due to a surge voltage, which is generated when the switching operation under an inductive load, exceeds Drain-Source breakdown voltage V_{DSS} of the MOSFET.



Drive circuit of the inductive load

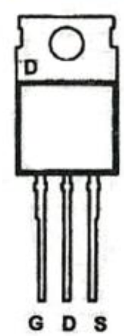
MOSFET – metal oxide semiconductor field effect transistor.

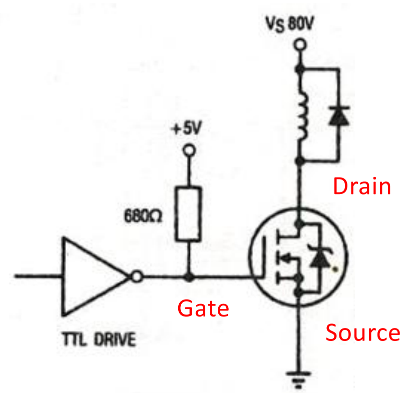
This type of device is not controlled by current, it is switched on or off by a voltage.

Applying a voltage above the gate threshold turns on the drain to source.

The main advantage of the MOSFET is the very low on resistance between the gate and source.

IRLZ24





1. GATE DRIVE VS BASE DRIVE

The conventional bipolar transistor is a current-driven device. As illustrated in Figure 1(a). a current must be applied between the base and emitter terminals to produce a flow of current in the collector. The amount of a drive required to produce a given output depends upon the gain, but invariably a current must be made to flow into the base terminal to produce a flow of current in the collector.

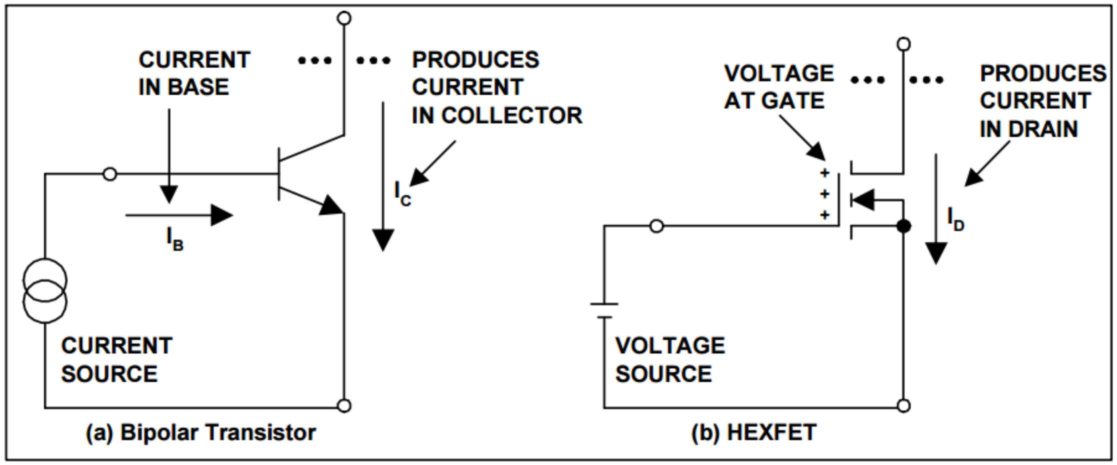


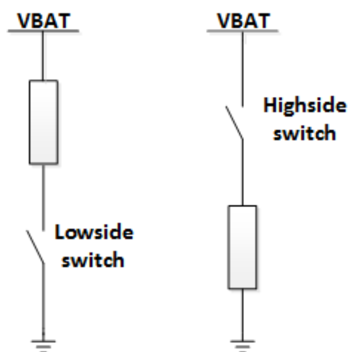
Figure 1. Bipolar Transistor is Current Driven, HEXFET is Voltage Driven

The HEXFET® is fundamentally different: it is a voltage-controlled power MOSFET device. A voltage must be applied between the gate and source terminals to produce a flow of current in the drain (see Figure 1b). The gate is isolated electrically from the source by a layer of silicon dioxide. Theoretically, therefore, no current flows into the gate when a DC voltage is applied to it - though in practice there will be an extremely small current, in the order of nanoamperes. With no voltage applied between the gate and source electrodes, the impedance between the drain and source terminals is very high, and only the leakage current flows in the drain.

What is a high-side/low-side driver in electronics?

First, realize that we say “high side”, we generally mean the power supply hot or +Vcc/Vdd side of the load. And when we say “low side”, we generally mean the neutral or ground/common/return side of the load.

On the left is a Low Side Driver. On the right is a High Side Driver.[1]

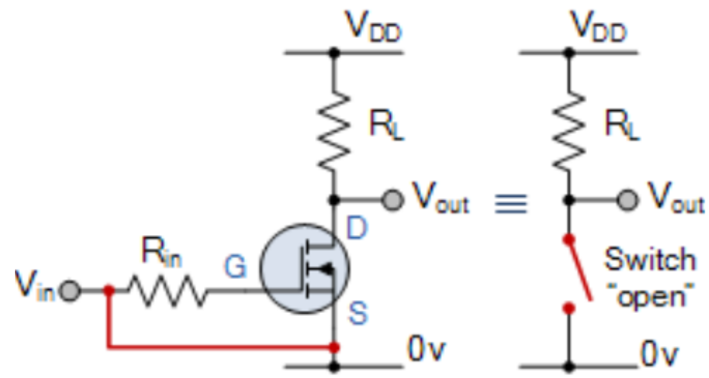


A high side driver is one in which the switching element is between Vcc and the load.

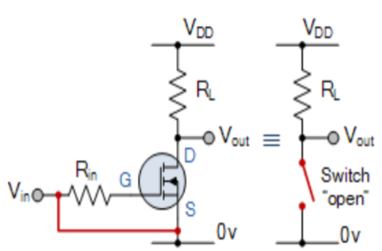
A low side driver is one in which the switching element is between the load and common.

1. Cut-off Region

Here the operating conditions of the transistor are zero input gate voltage (V_{IN}), zero drain current I_D and output voltage $V_{DS} = V_{DD}$. Therefore for an enhancement type MOSFET the conductive channel is closed and the device is switched “OFF”.



Cut-off Characteristics



- The input and Gate are grounded (0V)
- Gate-source voltage less than threshold voltage $V_{GS} < V_{TH}$
- MOSFET is “OFF” (Cut-off region)
- No Drain current flows (I_D = 0 Amps)
- $V_{OUT} = V_{DS} = V_{DD}$ = ”1”
- MOSFET operates as an “open switch”

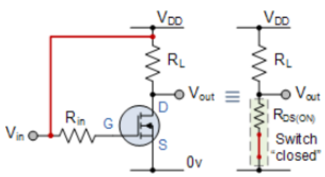
Then we can define the cut-off region or “OFF mode” when using an e-MOSFET as a switch as being, gate voltage, $V_{GS} < V_{TH}$ thus $I_D = 0$. For a P-channel enhancement MOSFET, the Gate potential must be more positive with respect to the Source.

Electronics Tutorials

2. Saturation Region

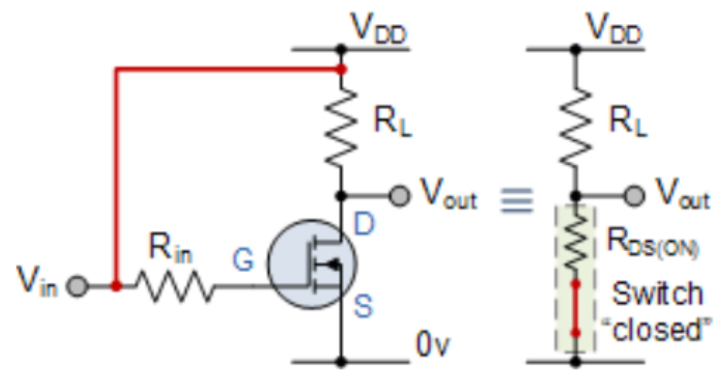
In the saturation or linear region, the transistor will be biased so that the maximum amount of gate voltage is applied to the device which results in the channel resistance $R_{DS(on}$ being as small as possible with maximum drain current flowing through the MOSFET switch. Therefore for the enhancement type MOSFET the conductive channel is open and the device is switched "ON".

Saturation Characteristics



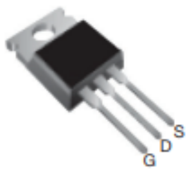
- The input and Gate are connected to V_{DD}
- Gate-source voltage is much greater than threshold voltage $V_{GS} > V_{TH}$
- MOSFET is "ON" (saturation region)
- Max Drain current flows ($I_D = V_{DD} / R_L$)
- V_{DS} = 0V (ideal saturation)
- Min channel resistance $R_{DS(on)} < 0.1\Omega$
- $V_{OUT} = V_{DS} \cong 0.2V$ due to $R_{DS(on)}$
- MOSFET operates as a low resistance "closed switch"

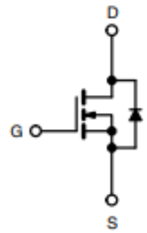
Then we can define the saturation region or "ON mode" when using an e-MOSFET as a switch as gate-source voltage, $V_{GS} > V_{TH}$ thus I_D = Maximum. For a P-channel enhancement MOSFET, the Gate potential must be more negative with respect to the Source.



ElectronicsTutorials

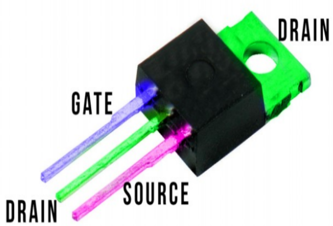
TO-220AB





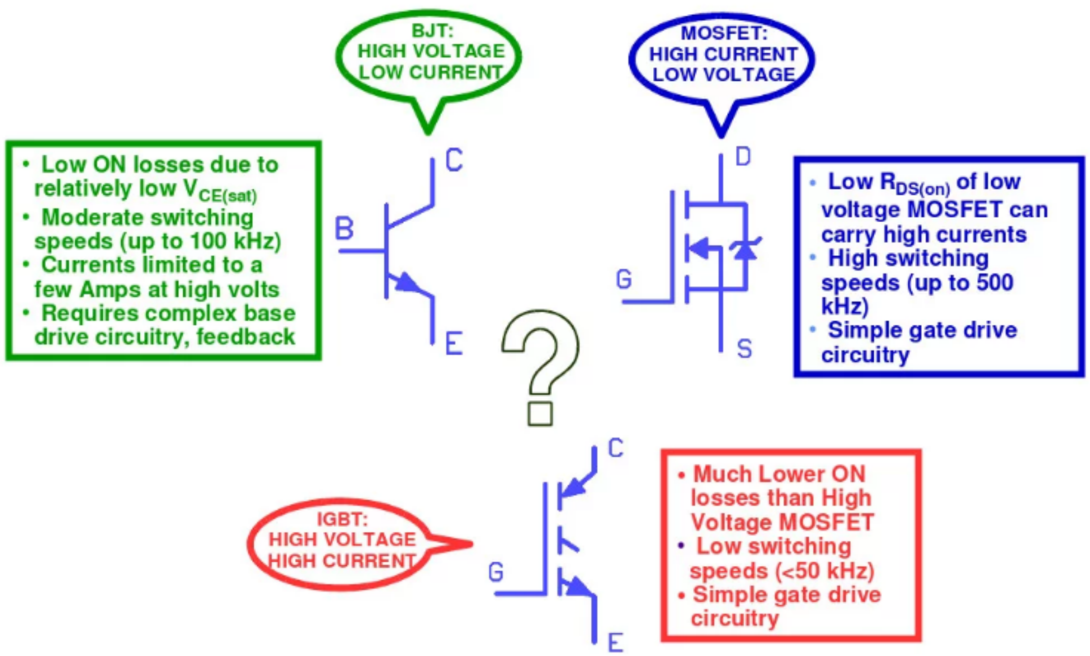
N-Channel MOSFET

ABSOLUTE MAXIMUM RATINGS (T_C = 25 °C, unless otherwise noted)					
PARAMETER			**SYMBOL**	**LIMIT**	**UNIT**
Drain-Source Voltage			V_{DS}	60	V
Gate-Source Voltage			V_{GS}	± 10	
Continuous Drain Current	V_{GS} at 5.0 V	T_C = 25 °C	I_D	17	A
		T_C = 100 °C		12	



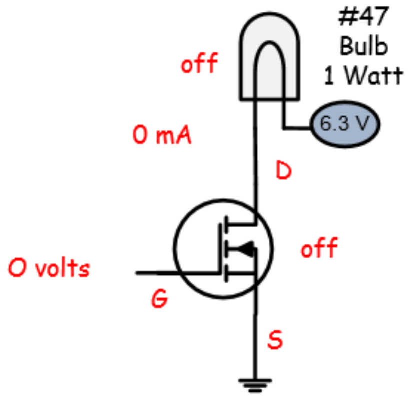
SPECIFICATIONS (T_J = 25 °C, unless otherwise noted)							
PARAMETER	**SYMBOL**	**TEST CONDITIONS**		**MIN.**	**TYP.**	**MAX.**	**UNIT**
Static							
Drain-Source Breakdown Voltage	V_{DS}	V_{GS} = 0 V, I_D = 250 µA		60	-	-	V
V_{DS} Temperature Coefficient	$\Delta V_{DS}/T_J$	Reference to 25 °C, I_D = 1 mA		-	0.060	-	V/°C
Gate-Source Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 250 µA		1.0	-	2.0	V
Gate-Source Leakage	I_{GSS}	V_{GS} = ± 10		-	-	± 100	nA
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} = 60 V, V_{GS} = 0 V		-	-	25	µA
		V_{DS} = 48 V, V_{GS} = 0 V, T_J = 150 °C		-	-	250	
Drain-Source On-State Resistance	$R_{DS(on)}$	V_{GS} = 5.0 V	I_D = 10 A[b]	-	-	0.10	Ω
		V_{GS} = 4.0 V	I_D = 8.5 A[b]	-	-	0.14	

High Power Transistor Technology Comparison

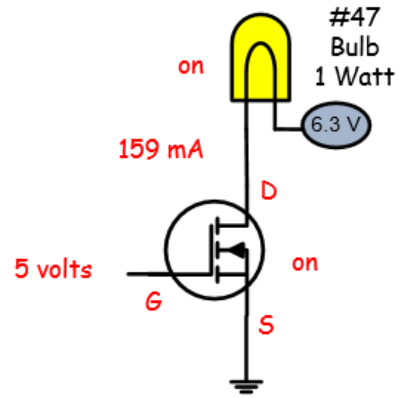


The metal–oxide–semiconductor field-effect transistor (**MOSFET**, MOS-FET, or MOS FET) is a type of transistor used for switching electronic signals. The device is controlled by a gate voltage.

IRLZ24 Logic Level MOSFET device



S-D infinite resistance

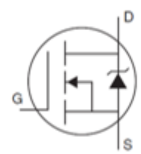


S-D almost 0 ohms

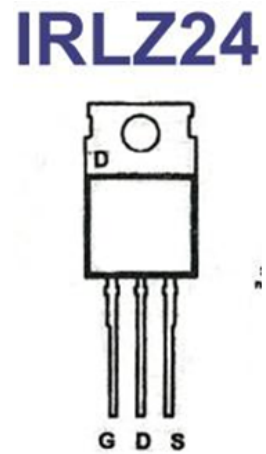
MOSFER Power = I^2R

Assume R_{DS} = 0.1 ohms

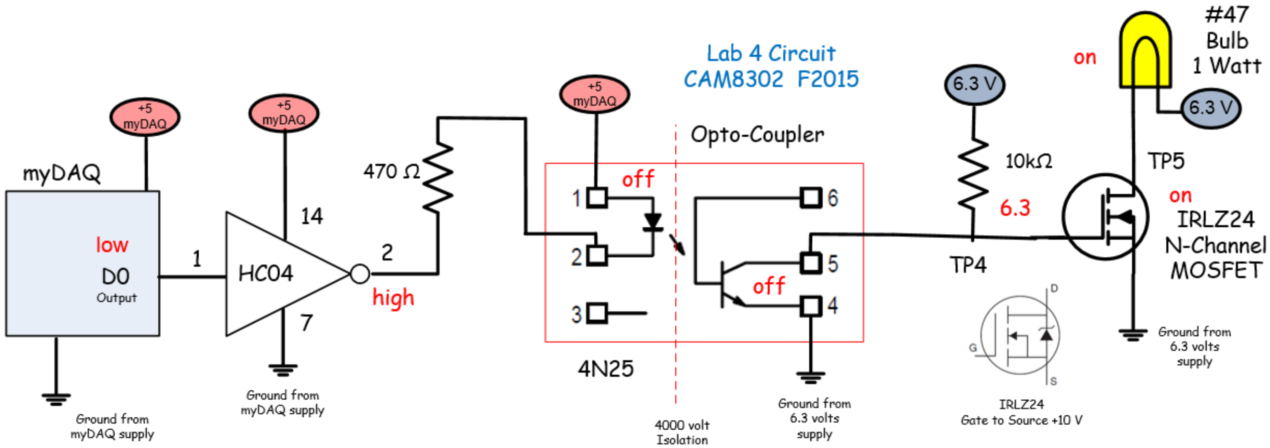
Power = 2.5 mWatts



IRLZ24
N-Channel
MOSFET



A MOSFET device is controlled with a voltage at the gate. When the voltage between the gate and source is greater than the threshold the device turns ON. The resistance between drain and source is about 0.1 ohms. When the gate is 0 volts the drain to source resistance is infinite.

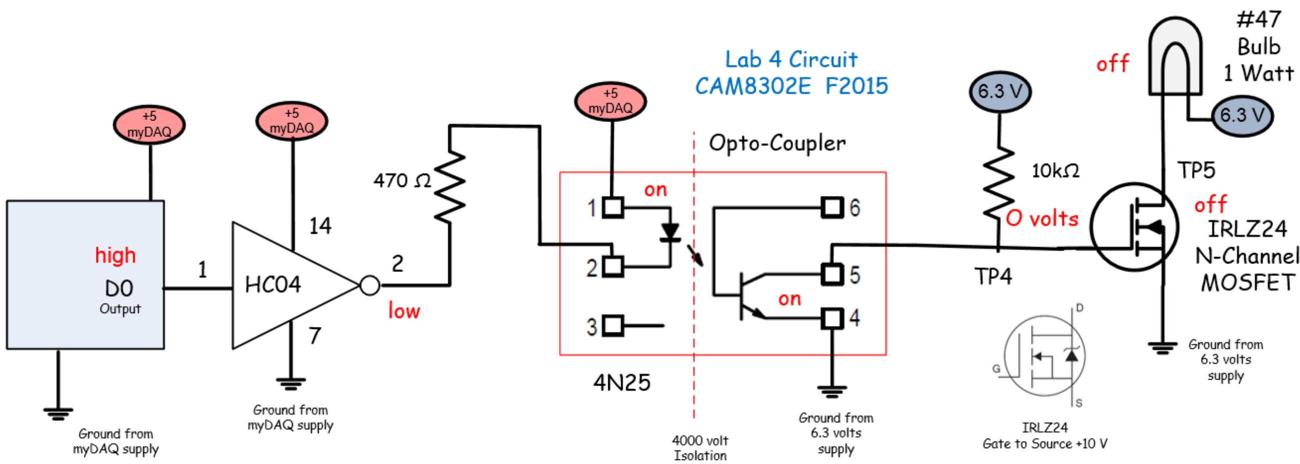


1) myDAQ o/p goes low, inverter o/p goes to about 4.7 volts.

2) With inverter output high the isolator IR led is off. The isolator transistor turns off.

3) The isolator transistor is open circuit and in a high impedance state, the pull up resistor provides 6.3 volts to the gate of the MOSFET turning it ON.

4) The resistance between drain and source is about 0.1 ohms providing a ground path to the lamp to turn it ON.

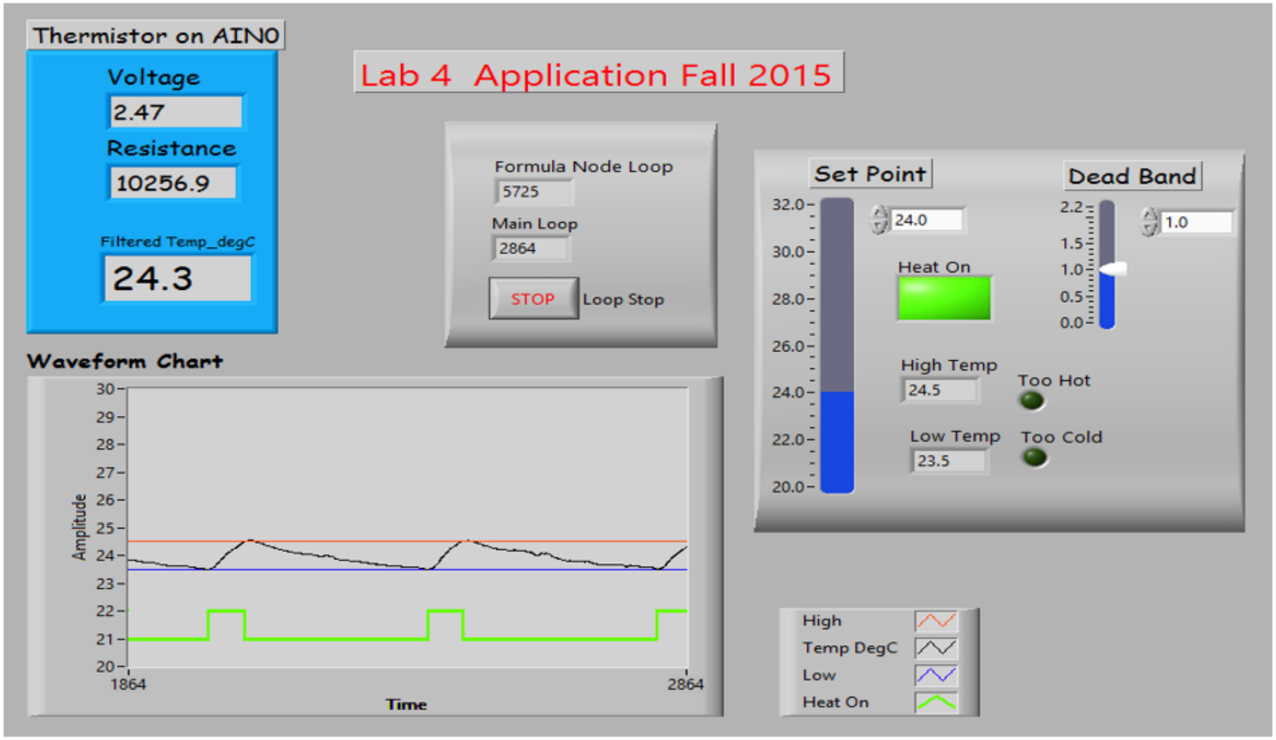


1) myDAQ o/p is high, inverter o/p goes low, about 0.2 volts.

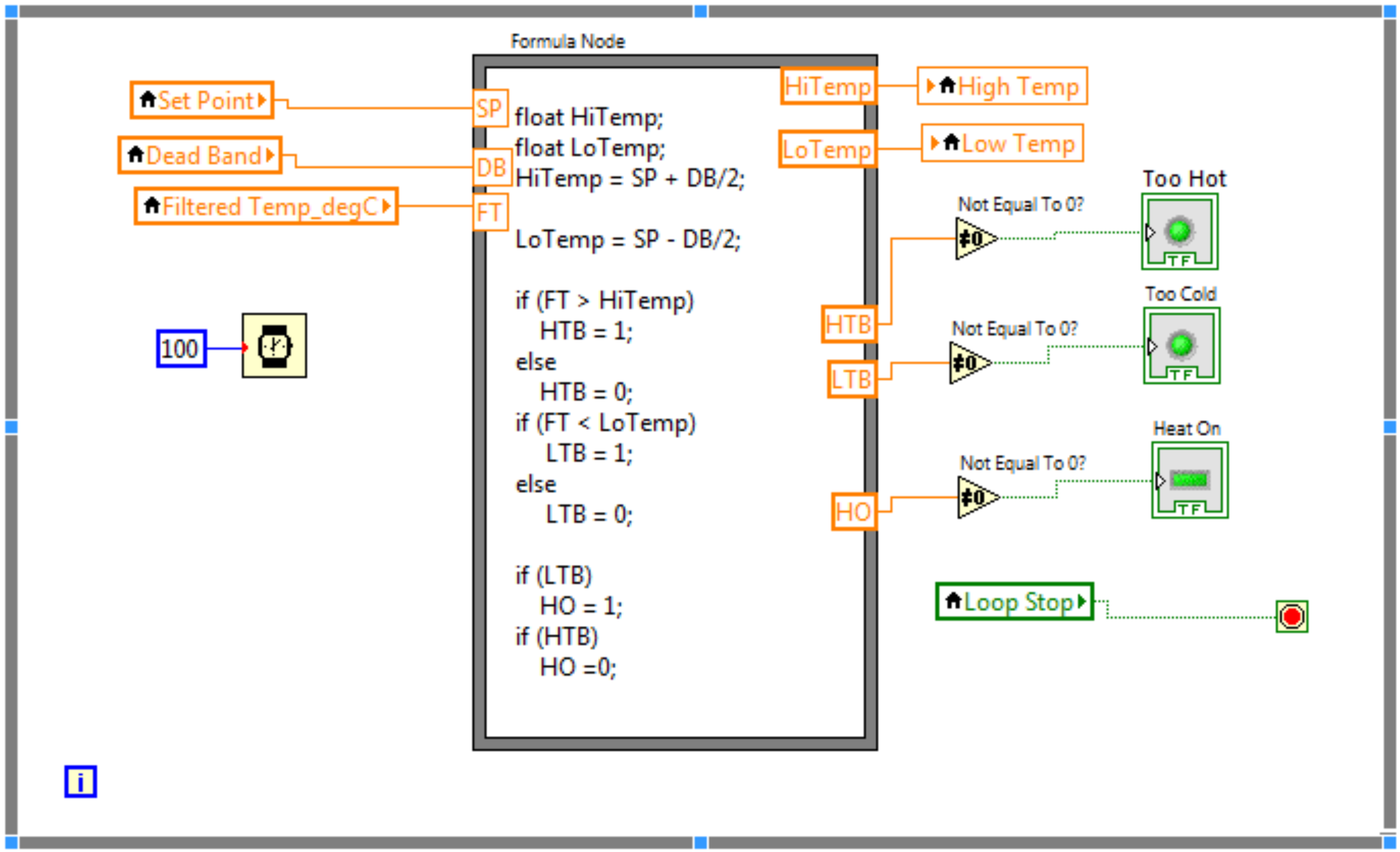
2) With the inverter output low the isolator IR led is on. The isolator transistor also turns on.

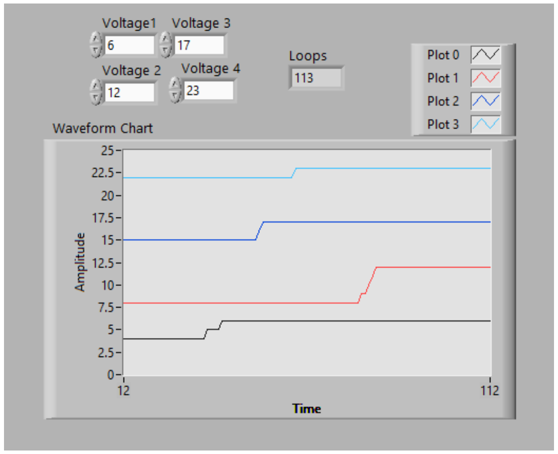
3) The isolator transistor acts as a closed switch grounding the gate of the MOSFET turning it OFF.

4) The resistance between drain and source is infinite (off), with an open circuit the lamp turns OFF.



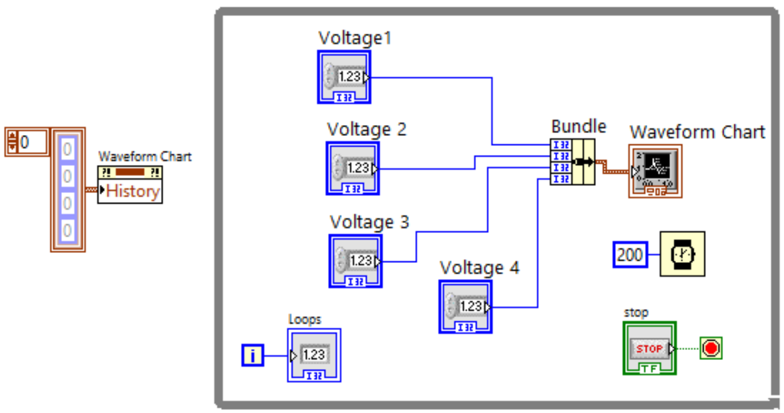
Lab 4 front panel: Chart indicates temperature, high and low limits and the state of the heater. The waveform is configured by right clicking on the chart and changing chart properties.

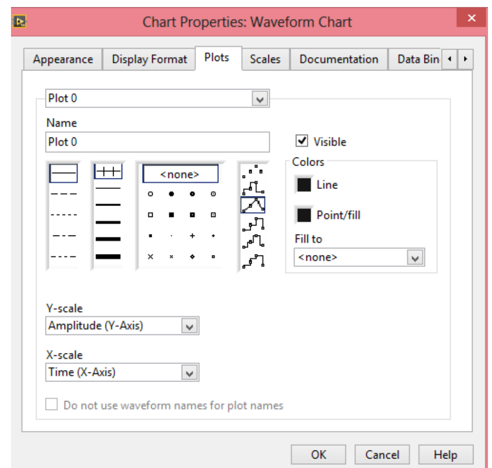

Formula Node
Set Point
Dead Band
Filtered Temp_degC
SP
DB
FT
float HiTemp;
float LoTemp;
HiTemp = SP + DB/2;
LoTemp = SP - DB/2;
if (FT > HiTemp)
HTB = 1;
else
HTB = 0;
if (FT < LoTemp)
LTB = 1;
else
LTB = 0;
if (LTB)
HO = 1;
if (HTB)
HO =0;
HiTemp
LoTemp
HTB
LTB
HO
High Temp
Low Temp
Too Hot
Too Cold
Heat On
Not Equal To 0?
Not Equal To 0?
Not Equal To 0?
100
Loop Stop
i

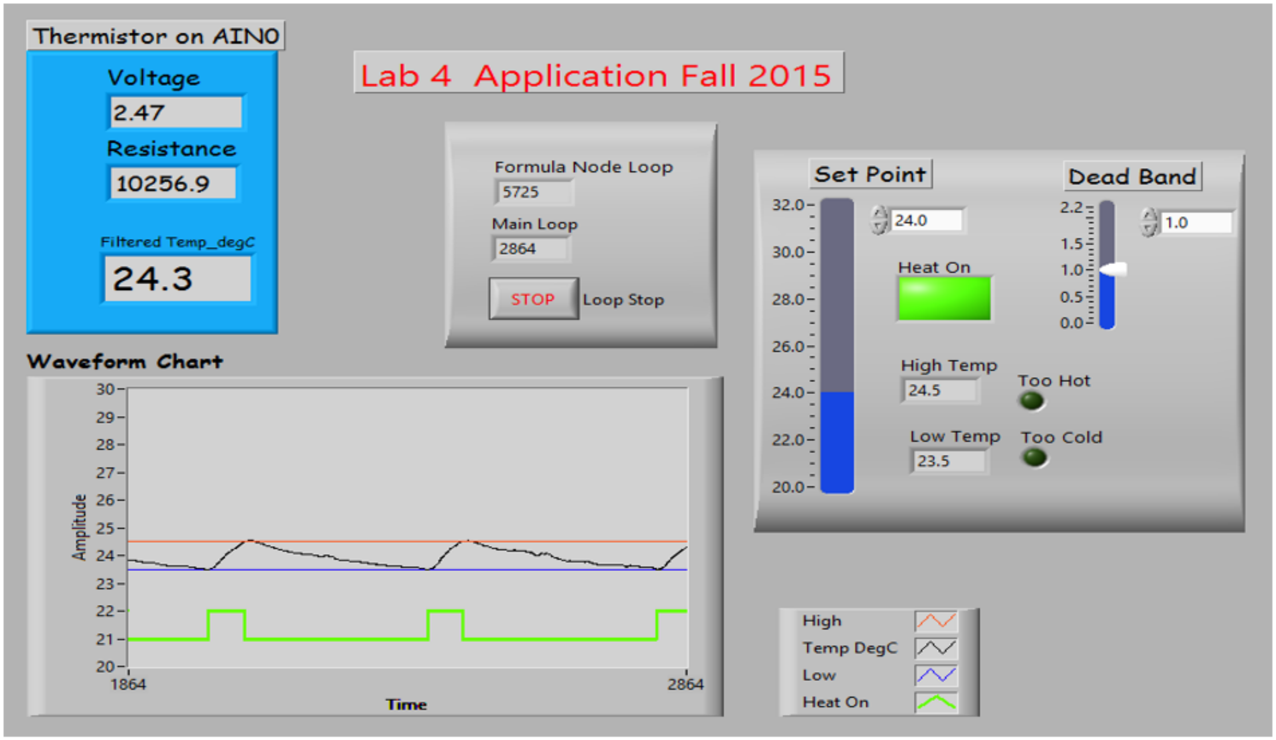


A waveform chart can have multiple inputs. A Bundle function is used to allow many inputs applied to a waveform chart. Each plot is configured under chart properties.

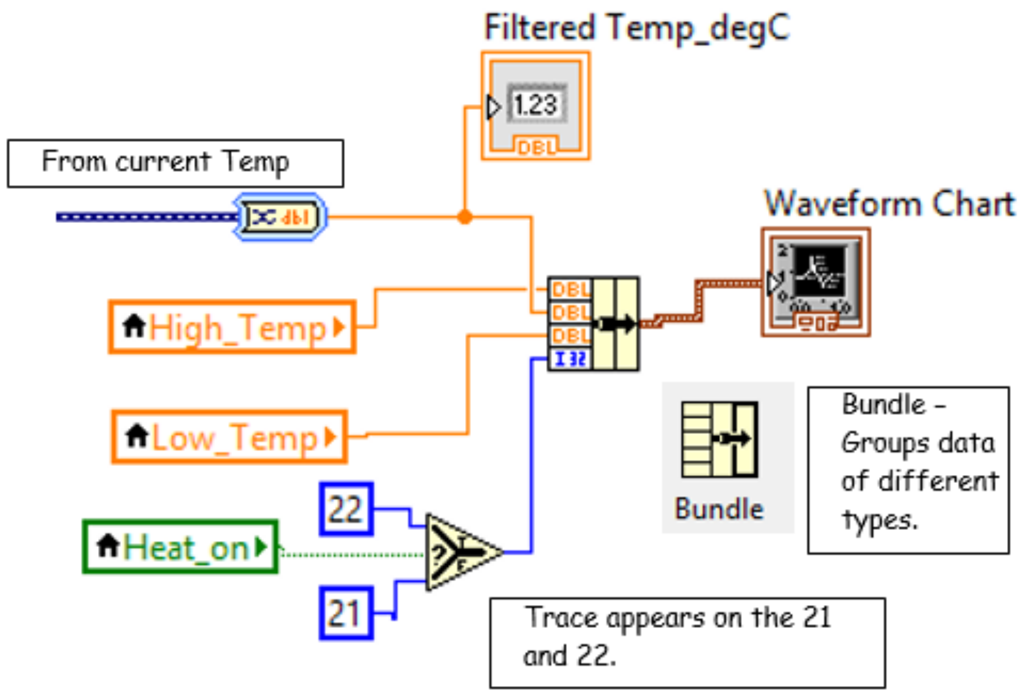
The chart can be cleared (programmatically) by creating a property node. A property node allows properties to be modified while the program is executing.





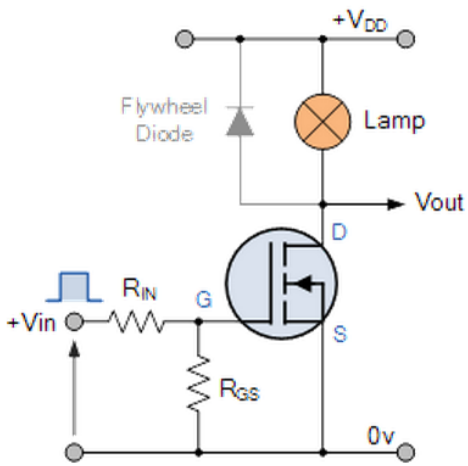


Lab 4 front panel: Chart indicates temperature, high and low limits and the state of the heater. The waveform is configured by right clicking and the chart and changing chart properties.



A bundle represents a group of various data type, the bundle can contain real, Boolean and integer data types. Four signal are being applied to the input of the waveform chart that will produce four signal traces. One for the temperature, the high limit, the low limits and the state of the heater.

An example of using the MOSFET as a switch



In this circuit arrangement an Enhancement-mode N-channel MOSFET is being used to switch a simple lamp "ON" and "OFF" (could also be an LED). The gate input voltage V_{GS} is taken to an appropriate positive voltage level to turn the device and therefore the lamp load either "ON", ($V_{GS} = +ve$) or at a zero voltage level that turns the device "OFF", ($V_{GS} = 0$).

If the resistive load of the lamp was to be replaced by an inductive load such as a coil, solenoid or relay a "flywheel diode" would be required in parallel with the load to protect the MOSFET from any self generated back-emf.

Above shows a very simple circuit for switching a resistive load such as a lamp or LED. But when using power MOSFETs to switch either inductive or capacitive loads some form of protection is required to prevent the MOSFET device from becoming damaged. Driving an inductive load has the opposite effect from driving a capacitive load.

For example, a capacitor without an electrical charge is a short circuit, resulting in a high "inrush" of current and when we remove the voltage from an inductive load we have a large reverse voltage build up as the magnetic field collapses, resulting in an induced back-emf in the windings of the inductor.

MOSFET Type	V_{GS} (+ve)	V_{GS} (0v)
N-channel Enhancement	ON	OFF

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Power MOSFET Motor Control

Because of the extremely high input or gate resistance that the MOSFET has, its very fast switching speeds and the ease at which they can be driven makes them ideal to interface with op-amps or standard logic gates. However, care must be taken to ensure that the gate-source input voltage is correctly chosen because when using the **MOSFET as a switch** the device must obtain a low $R_{DS(on)}$ channel resistance in proportion to this input gate voltage.

Low threshold type power MOSFETs may not switch "ON" until a least 3V or 4V has been applied to its gate and if the output from the logic gate is only +5V logic it may be insufficient to fully drive the MOSFET into saturation. Using lower threshold MOSFETs designed for interfacing with TTL and CMOS logic gates that have thresholds as low as 1.5V to 2.0V are available.

Power MOSFETs can be used to control the movement of DC motors or brushless stepper motors directly from computer logic or by using pulse-width modulation (PWM) type controllers. As a DC motor offers high starting torque and which is also proportional to the armature current, MOSFET switches along with a PWM can be used as a very good speed controller that would provide smooth and quiet motor operation.

MOSFET as a Switch Example No1

Lets assume that the lamp is rated at 6v, 24W and is fully "ON", the standard MOSFET has a channel on-resistance ($R_{DS(on)}$) value of 0.1ohms. Calculate the power dissipated in the MOSFET switching device.

The current flowing through the lamp is calculated as:

$$P = V \times I_D$$

$$\therefore I_D = \frac{P}{V} = \frac{24}{6} = 4.0\,\text{amps}$$

Then the power dissipated in the MOSFET will be given as:

$$P = I^2.R$$

$$P_D = I_D^2 \times R_{DS}$$

$$\therefore P_D = 4^2 \times 0.1 = 1.6\,\text{watts}$$

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You may be sat there thinking, well so what!, but when using the MOSFET as a switch to control DC motors or electrical loads with high inrush currents the "ON" Channel resistance ($R_{DS(on)}$) between the drain and the source is very important. For example, MOSFETs that control DC motors, are subjected to a high in-rush current when the motor first begins to rotate, because the motors starting current is only limited by the very low resistance value of the motors windings.

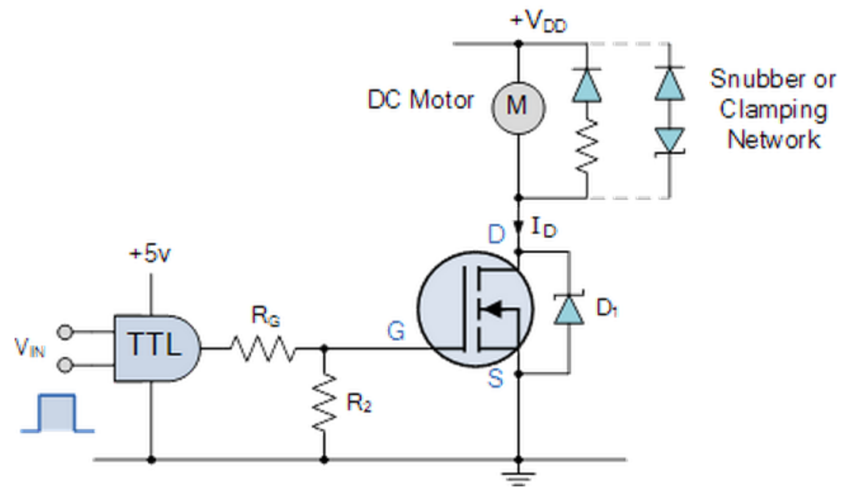
As the basic power relationship is: $P = I^2R$, then a high $R_{DS(on)}$ channel resistance value would simply result in large amounts of power being dissipated and wasted within the MOSFET itself resulting in an excessive temperature rise, which if not controlled could result in the MOSFET becoming very hot and damaged due to a thermal overload.

A lower value $R_{DS(on)}$ on the other hand, is also a desirable parameter as it helps to reduce the channels effective saturation voltage ($V_{DS(sat)} = I_D \times R_{DS(on)}$) across the MOSFET and will therefore operate at a cooler temperature. Power MOSFETs generally have a $R_{DS(on)}$ value of less than 0.01Ω which allows them to run cooler, extending their operational life span.

One of the main limitations when using a MOSFET as a switching device is the maximum drain current it can handle. So the $R_{DS(on)}$ parameter is an important guide to the switching efficiency of the MOSFET and is simply given as the ratio of V_{DS} / I_D when the transistor is switched "ON".

When using a MOSFET or any type of field effect transistor for that matter as a solid-state switching device it is always advisable to select ones that have a very low $R_{DS(on)}$ value or at least mount them onto a suitable heatsink to help reduce any thermal runaway and damage. Power MOSFETs used as a switch generally have surge-current protection built into their design, but for high-current applications the bipolar junction transistor is a better choice.

Simple Power MOSFET Motor Controller



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As the motor load is inductive, a simple flywheel diode is connected across the inductive load to dissipate any back emf generated by the motor when the MOSFET turns it "OFF". A clamping network formed by a zener diode in series with the diode can also be used to allow for faster switching and better control of the peak reverse voltage and drop-out time.

For added security an additional silicon or zener diode D_1 can also be placed across the channel of a MOSFET switch when using inductive loads, such as motors, relays, solenoids, etc, for suppressing over voltage switching transients and noise giving extra protection to the MOSFET switch if required. Resistor R_2 is used as a pull-down resistor to help pull the TTL output voltage down to 0V when the MOSFET is switched "OFF".