Integration of Power and Sensors

Power for Microcontroller

Can Use 4 AA batteries, which is equivalent to 6 Volts.

Problem: AA batteries may not last very long, even with super alkaline.

Alternative solution:

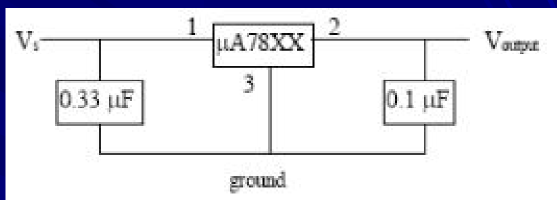
*** Use 6V accumulators of higher capacity. Apart from accumulators, the more efficient (and costly) lithium polymer batteries can be used.**

*** Use accumulator of higher voltage & capacity, with a regulator circuit to step down the supply voltage**

*** Capacity of battery is measured in terms of AH, namely Ampere-Hour. As the name says, a battery of 1AH will last for 1 hour if a continuous current of 1A is drawn from it. As capacity becomes lower, the nominal voltage of the battery also drops lower.**

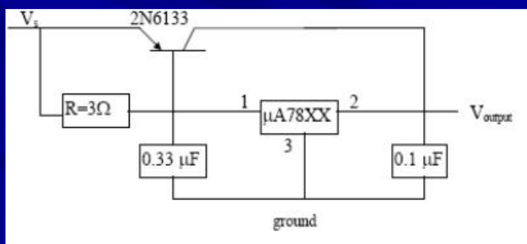
Voltage Regulator Circuit 1

Voltage regulators are mainly used to step-down a supply voltage in applications where more than 1 supply voltage is required, i.e. 24V, 12V and 5V needed in the same application circuit.



Voltage Regulator Circuit 2

If current requirement is more than 1 amp but less than 3 amperes, a transistor can be added to boost up the current supply.



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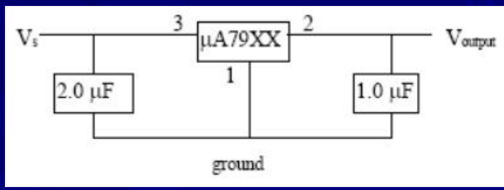
Integration of Power and Sensors Pg.3

Voltage Regulator Circuit 3

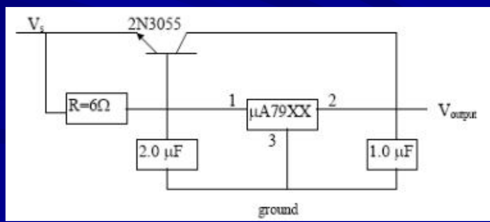
If a negative voltage is required, another range of voltage regulators is needed. In addition, a negative voltage source is also needed for this regulator. The regulators for negative outputs are of the 79XX range.

Sample circuit if current drawn is less than 1 ampere.



Voltage Regulator Circuit 4

If current requirement is more than 1 amp but less than 3 amp, a transistor can be added to boost up the current supply as in the positive regulator, except that the transistor is of a different type.



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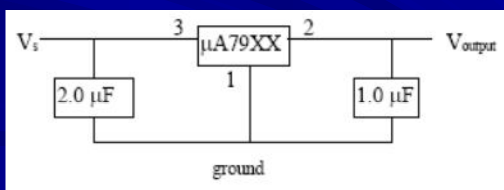
Other Components in Power Circuits

In all the 4 regulator circuits shown earlier, you see capacitors being placed at many locations. The purpose of the capacitors is to maintain a stable voltage within the circuit. In an actual circuit, current consumption may vary suddenly, such as when you switch on or off a motor. This sudden surge in current demand may cause a voltage glitch, i.e. a sudden drop of voltage across the circuit. If the glitch is huge, say up to 50%, a +5V supply may drop to +2V. To a MicroController, this would mean a system RESET!! A capacitor will help to eliminate such glitches.

Another device you may see is a diode, which controls the flow of current (power) in a particular direction. This helps to protect the circuit against reversed power connection or reversed power flow, thus keeping the chips in working order. A set of 4 diodes can also be used as a rectifier, ensuring the output to be in a desired polarity.



Integration of Power and Sensors Pg.5

Charging of batteries

After using for some time, accumulators or Li-Ion batteries need to be re-charged to capacity.

For all types of rechargeable batteries, **use only the recommended chargers, as they would be able to charge the batteries in a manner to maximise the life cycle of the batteries and not cause any damage. Using other types of chargers may damage the batteries, and in more extreme cases, cause explosion!! This is especially true for Li-Ion batteries.**

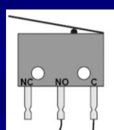
For accumulators, if you do not have a charger, you may use a DC power supply to charge the battery, but under constant monitoring. If possible, use power supplies with current indicators, so that you know when the battery is fully charged, i.e. when the current drawn is very small, like 50mA.

Integration of Power and Sensors Pg.6

Digital / logical sensors

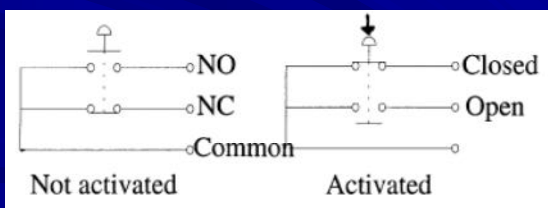
Digital input ports are meant for logic sensors, which provide a clear and distinct TRUE (1 or +5V) or FALSE (0 or 0V) signal. There are no in-between signals, but the signals may fluctuate when the states are unclear.

Sample 1 of logic sensors : touch sensors or limit switches.



The symbolic or circuit representation of the limit switch can be simplified as:

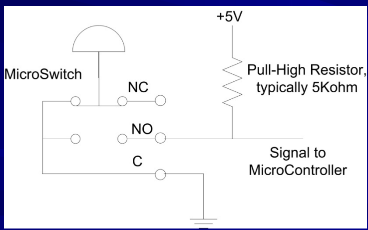
NO – Normally Open
NC – Normally Closed
C – Common



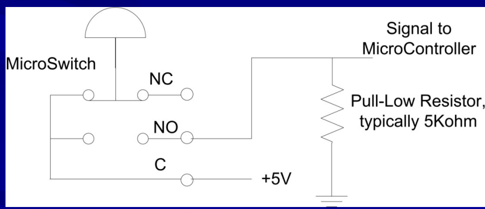
Digital / logical sensors

Let's look at the connections to the microswitch. The Common (C) pin must be connected to either the V+ or Ground. When C is connected to Ground, if the Normally Open (NO) pin is used and is connected to the MicroController (MC), the Signal which is transmitted to the MC shall be Ground or FALSE (0 V) when the microswitch is activated. When the microswitch is not activated, there will be no signal at the NO pin, as it is an Open Circuit. This posed a problem as the MC cannot tell the state. Open Circuit could be either High or Low, as the wire might catch electromagnetic waves in the air and produce some potential difference.

In order to overcome this uncertainty, a Pull-High Resistor must be added to the Signal line. By doing so, when the NO pin was open, the Pull-High Resistor will ensure the signal is High. The Signal will only turn Low when the switch is activated and the Signal line is shorted to Ground.

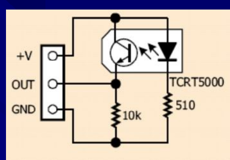


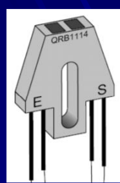
Pull-High Resistor Setup



Pull-Low Resistor Setup

Sample 2 of logic sensors : Light Reflector or IR sensors





This sensor is made up of a pair of IR emitter & corresponding IR detector. In the right hand side figure, the 510 ohm resistor is used to limit the current flowing through the IR emitter, thus controlling the amount of IR being produced. It also prevents the emitter from being over powered and getting itself burnt. You may reduce the resistor value to increase the IR density so as to increase the sensing distance.

The 10K resistor helps to produce the signal when the detector senses IR rays. IR light will cause the transistor to allow current to flow through, just as a base current in a normal transistor, and produces a voltage across the resistor. The higher the resistor value, the more sensitive the detector becomes.

Please be aware, that there are small amount of IR in the surrounding, ranging from the domestic fluorescent tubes (small amount of IR) to direct sun light (which may be of quite significant amount.) Automatic devices, such as auto-focus cameras and video equipment also makes use of IR for range finding, and their signal will affect the result of the sensor.

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Integration of Power and Sensors Pg.8

Analog sensors

The analog input ports are meant for sensors which return a voltage signal between 0 V and +5 Volts. The input voltage has to be calibrated against some physical quantity, such as distance, brightness, loudness, position, etc.

The value which the program will receive from the analog input ports depends on the resolution of the analog-to-digital converter or ADC in short. For a 10-bit ADC, the biggest value you will get is 2^10-1=1023. In other words, an input above +5 Volts will produce a reading of 1023, while a 0 V produces 0. The rest of the voltages can be interpolated in a straight line.

For a given reading, the actual analog voltage can be calculated using the following equation:

Voltage = Reading / 1024 * 5.0

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Integration of Power and Sensors Pg.9

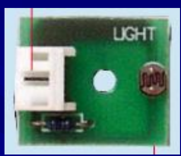
For example, if SENSOR reading is 427, then

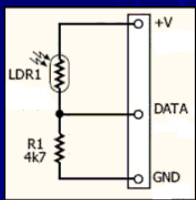
Voltage = 427 / 1024 * 5.0

= 2.085 Volts, down to 3 decimal places

Sample 1 for Analog Sensors: Light Sensors

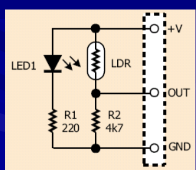
This sensor detects the light intensity and returns an analogue signal.





Sample 2 for Analog Sensors: LDR

This sensor is similar to the first one. It detects different light density & sends an analog signal back to the processor. The LDR comes with a Red LED, which acts as the light source instead of depending on the ambient light. This helps the sensor to differentiate different colour surfaces, depending on the amount of Red light being reflected.



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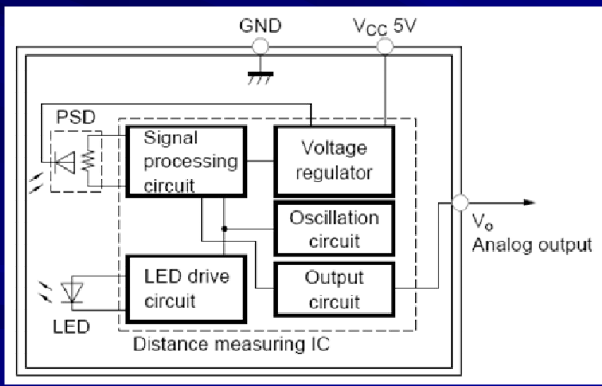
Integration of Power and Sensors Pg.10

Sample 3 for Analog Sensors: GP2D120

This sensor measures distance by sensing the strength of the reflected incident Infra-Red (IR) light. The optimum operation range is between 4 cm to 30 cm .



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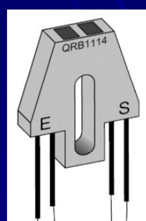
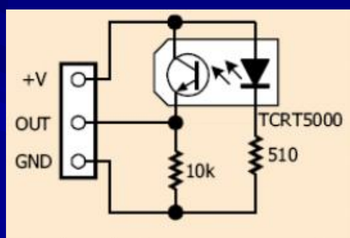
Integration of Power and Sensors Pg.11

Sensor 4 for Analog Sensors: Light Reflector or IR sensors

This sensor was categorised as a digital sensor earlier, but can also be used as an analog sensor. It can be used as a short range distance measurement sensor. By changing the sensitivities of the detector and the amount of IR, the distance range

can reach 10mm or more.





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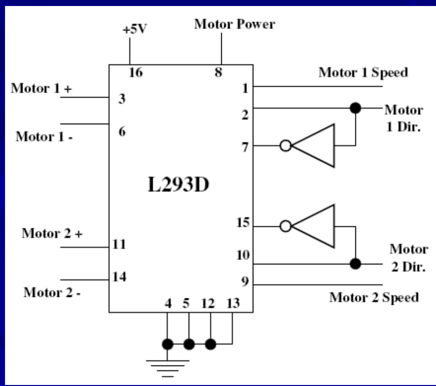
Simple Electronic Switch – H-Bridge

A simple electronic device can be used to help the logic signal to activate a device of higher voltage and current.

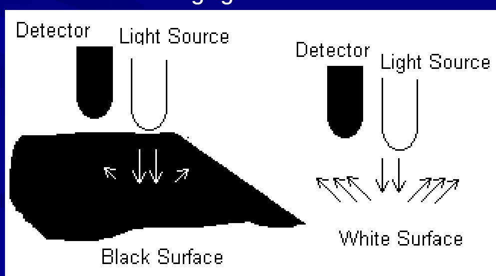
The L293D chip has got 2 pairs of H-Bridges, each pair being controlled by a common enable signal. Each H-Bridge can drive up to 1 Ampere in current, and the output voltage for all four bridges can be tapped from a separate source at pin 8. The example on the right shows bi-directional driving of 2 dc Motors with the L293D chip.



Line Tracking

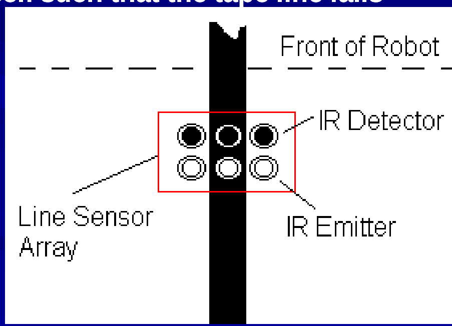
A line sensor in its simplest form is a sensor capable of detecting a contrast between adjacent surfaces, such as difference in color, roughness, or magnetic properties, for example. The simplest would be detecting a difference in color, for example black & white surfaces. Using simple optoelectronics, such as infrared photo-transistors, color contrast can easily be detected. Infrared emitter/detectors or photo-transistors are inexpensive (usually under $1 per sensor) & are easy to interface to a MC. In addition, standard red LEDs & Cds photocells work well too & fall in the same price range as the infrared photo-transistors.

When light shines on a white surface, most of the incoming light is reflected away from the surface. In contrast, most of the incoming light is absorbed if the surface is black. Therefore, by shining light on a surface & having a sensor to detect the amount of light that is reflected, a contrast between black & white surfaces can be detected. The figure on the right shows an illustration of the basics just covered.



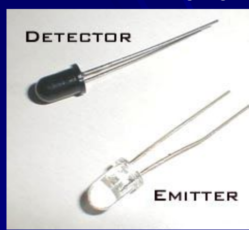
Line Tracking Pg.2

Using what we know about light, and black and white surfaces, the objective of tracking a line is simple can be achieved using the appropriate sensors. Let us consider the use of three pairs of emitter & detector as shown in the figure below. The drive configuration for the robot is assumed to be differential, i.e., like the tracks of an army tank vehicle. From the figure, the three pairs of sensors are used to keep the robot on the line as it moves. Each sensor output is monitored to determine the location of the tape relative to the robot. The main objective of the robot is to position itself such that the tape line falls between the 2 extreme sensors. If the tape line ever ventures past these two extreme sensors, then the robot corrects by turning in the appropriate direction to maintain tracking. Two different types of light sensors set up in the configuration shown below will be used for line tracking.

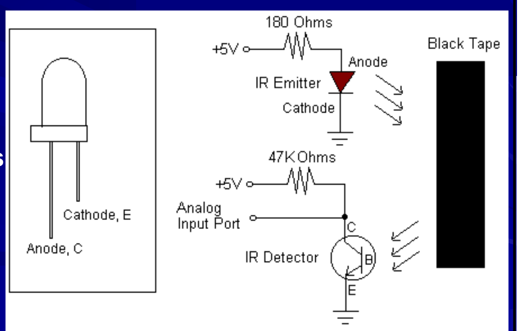


Line Tracking Pg.3

Constructing the line sensor is straightforward. A prototype should be made to test the operation of the sensor before committing to any permanent construction. You can either build the infrared version or the version which uses red LEDs and Cds photocells for this purpose. The infrared emitter & detector sensors are shown below. You can buy these from Sim Lim Tower or online from Farnell or RS Comp.



The circuit diagram is shown below & only one set of emitter/detector sensor is depicted. The remaining two are constructed in the same manner. Pay close attention to the anode (+V) & cathode (GND) lead for these sensors. If you plan on making the sensor from color LEDs & Cds photocells, use the same circuit diagram shown below, but replace the IR emitter with a red LED & the IR detector with a Cds photocell.



Line Tracking Pg.4

Each detector sensor can be connected to the digital or analog input port of the microcontroller board. Since the output of each detector may vary in range depending on the type of surface, the black and white tolerance should be adjusted accordingly.

When you are configuring the sensors, the following issues will have to be taken into consideration:

1. The number of sensors, be it 3, 5 or even more depending on the speed of the robot, the width of the tracking tape as well as the smallest curve the robot has to navigate through. A larger number of sensors will be more advantageous if the speed is higher and the curvature smaller, i.e. higher likelihood of getting off track.
2. Leave sufficient space to physically adjust the sensors. Depending on the distance between the sensors and the track surface, the best angle between the emitter and detector in order to direct the incident light may vary for best performance.

Line Tracking Pg.5

3. The distance between adjacent sensors depend mainly on the tracking tape width. If you have a wider sensing tape, you can afford less sensors and wider spacing between sensors.
4. In order to reduce noise from the surrounding, such as ambient light and IR from auto-focus devices (especially for IR sensors), the emitter & detector pair should be shielded with black sleeves. One possible solution would be to use black heat shrink tubes to wrap around the sensors, leaving only the front opening. This will also reduce the sensitivity of the detector from direct stray light from the emitter. In addition, the whole sensor block should preferably be shielded from ambient (light) noise.
5. Mounting of the sensor block should be relatively stable and rigid. It should also be placed near the front end.

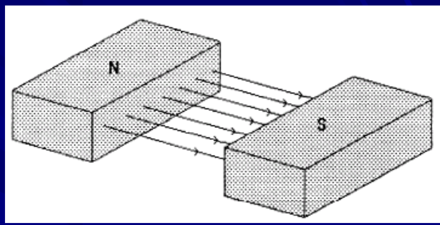
Mechanical Engineering Design

DC Motors and Their Drivers Pg.1

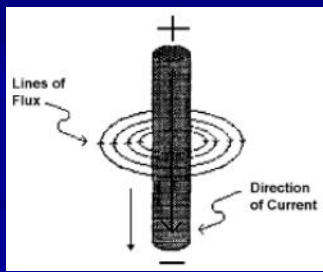
DC Motors and Their Drivers

Basics of a DC Motor

Magnetic strength is determined by the density of magnetic flux, which flows from the North pole to the South pole.



When current flows through a wire, a magnetic flux is generated around the wire according to the right hand rule, assuming current flows from +ve to –ve and the flux direction N to S.



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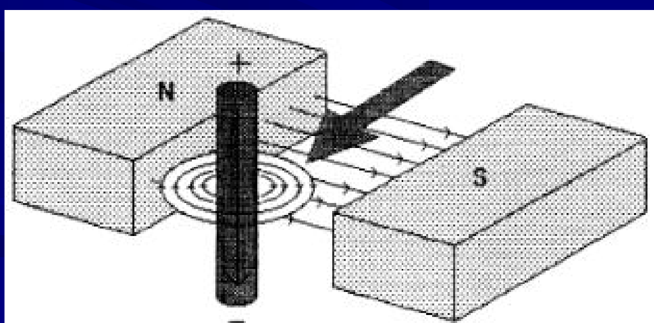
Mechanical Engineering Design

DC Motors and Their Drivers Pg.2

Basics of a DC Motor (con't)

When live wire (with DC current flowing) is placed into a magnetic field, a force is generated, which will push the wire to side where the magnetic flux is weaker.

The force generated is proportional to the strength of the magnetic flux, Φ and the current flowing in the wire, I.



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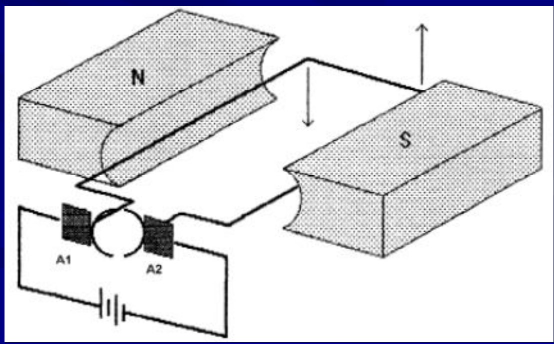
Basics of a DC Motor (con't)

When this effect is optimised and configured in a loop, with a brush to change the flow of current in the wire, the resultant linear motion can be transformed into a rotational motion and the linear force transformed into effective torque.



Basics of a DC Motor (con't)

The torque generated can be calculated as:

$$T = K_t \Phi_F I_A$$

where

T = Torque	K_t = Torque constant
Φ_F = Field Flux	I_A = Armature current

The rotational speed of the motor is determined by:

$$N = (E_T - I_A R_A) / K_V \Phi_F$$

where

N = speed	E_T = terminal voltage
I_A = Armature current	R_A = armature resistance
K_V = voltage constant	Φ_F = Field Flux

In practice, the wire will be wound into a core of multiple loops.

General Motor Drives

2 main characteristics of the DC motor are:

- Speed is proportional to the applied voltage
- Current is proportional to the load carried by the motor.

Thus, in order to control the motor performance, logically speaking, we should be controlling the voltage being sent to the motor, with sufficient current limit from the source.

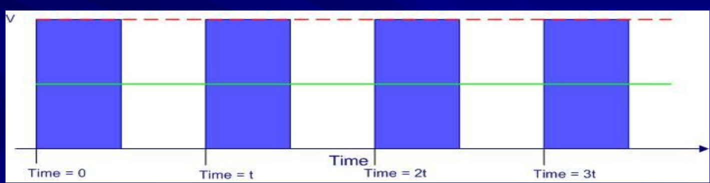
This is not done in practice, as variable analog voltage output with large current is not available, and is not practical.

The solution is to efficiently control the power being sent to the motor through the PWM method.

Introduction to Pulse Width Modulation (PWM)

A PWM signal consists of a fixed frequency logic pulse train with controllable duty cycle.

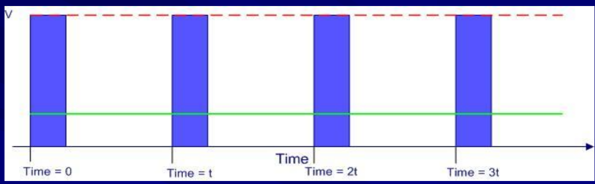
Imagine a normal clock signal, i.e. 50% duty cycle, as shown below is sent to an electronic switch.



The blue section will be the switch-on period. If applied voltage is V, then the equivalent voltage is V/2, as shown by the green line, which is 50% of V.

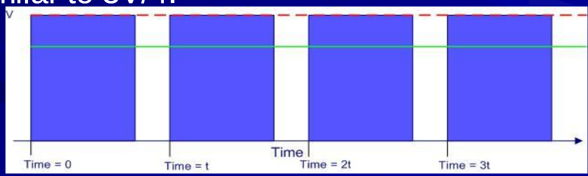
PWM (con't)

If a lower duty cycle is set, say 25%, then the PWM signal will look like this.



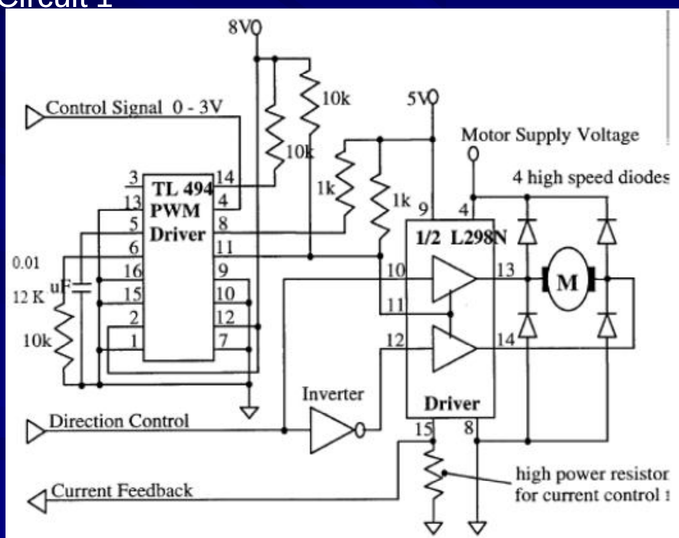
The equivalent output voltage shall then be V/4.

If a higher duty cycle of 75% is used, then the output will be similar to 3V/4.



PWM (con't)

PWM Circuit 1



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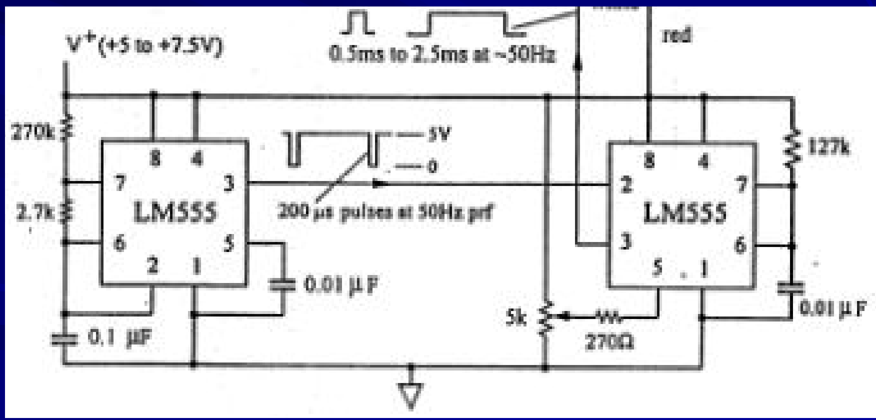
DC Motors and Their Drivers Pg.9

PWM (con't)

PWM Circuit 2

Using 2 LM555 timer chips. PWM is controlled by 5Kohm variable resistor.



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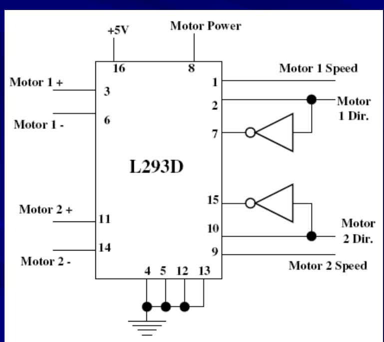
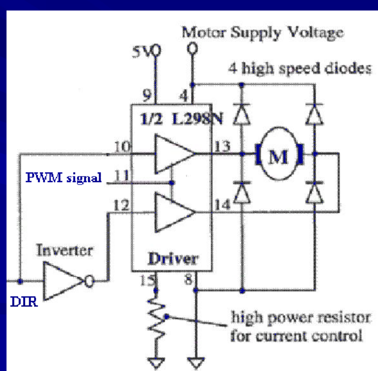
Mechanical Engineering Design

DC Motors and Their Drivers Pg.10

PWM (con't)

PWM signals can also be generated by many Microcontrollers directly, without having to build external circuitries. For such situations, only the driver circuits need be incorporated. Examples of Driver chips are the L293D and the L298N.





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Mechanical Engineering Design

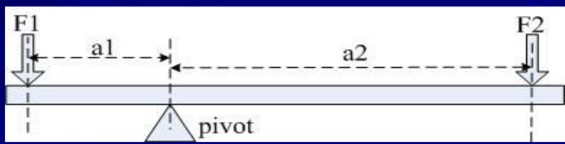
DC Motors and Their Drivers Pg.11

Gears & Gearbox

Principles of operation for gear trains are similar to that of the lever. In the lever system, the balancing force is inversely proportional to the moment arm, as shown below.

In equilibrium:

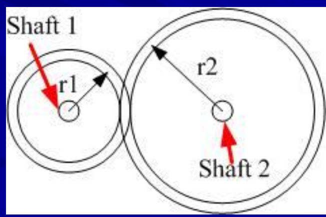
F1.a1 = F2.a2



Gears are normally used to change the output torque and speed of a rotary actuator.

The input shaft is connected to the actuator and normally to a smaller gear.

The output shaft connects to the wheel or linkages and a bigger gear.



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DC Motors and Their Drivers Pg.12

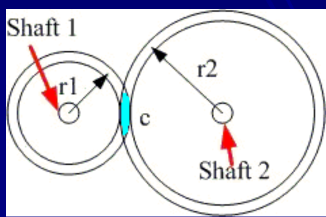
Gears & Gearbox (con't)

If Shaft 1 = input shaft & Shaft 2 = output shaft

Let T1 = input torque, T2 = output torque

w1 = input rotational speed, and

w2 =output rotational speed



Then,

w2 = w1 x r1 / r2, and T2 = T1 x r2 / r1

Thus, if r2 > r1 then

w2 < w1, and T2 > T1

The gears can be appended to create gear trains to achieve higher magnification factors, but the efficiency can take a beating !!

Huge gear trains can have efficiency as low as 20%, due to friction, etc.

Multiple gears placed in plenary manner may increase the efficiency slightly.

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RC Servo Motors

A Servo is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes. In practice, servos are used in radio controlled airplanes to position control surfaces like the elevators and rudders. They are also used in radio controlled cars, puppets, and of course, robots.

Servos are extremely useful in robotics. The motors are small, as you can see by the picture on the right, have built in control circuitry, and are extremely powerful for their size. A standard servo such as the Futaba S-148 has 42 oz/inches of torque, which is pretty strong for its size. It also draws power proportional to the mechanical load. A lightly loaded servo, therefore, doesn't consume much energy. The guts of a servo motor are shown in the picture below. You can see the control circuitry, the motor, a set of gears, and the case. You can also see the 3 wires that connect to the outside world. One is for power (+5volts), ground, and the white wire is the control wire.

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So, how does a servo work? The servo motor has some control circuits and a potentiometer (a variable resistor) that is connected to the output shaft. In the picture above, the pot can be seen on the right side of the circuit board. This pot allows the control circuitry to monitor the current angle of the servo motor. If the shaft is at the correct angle, then the motor shuts off. If the circuit finds that the angle is not correct, it will turn the motor the correct direction until the angle is correct. The output shaft of the servo is capable of traveling somewhere around 180 degrees. Usually, it is somewhere in the 210 degree range, but it varies by manufacturer. A normal servo is used to control an angular motion of between 0 and 180 degrees. A normal servo is mechanically not capable of turning any farther due to a mechanical stop built on to the main output gear.

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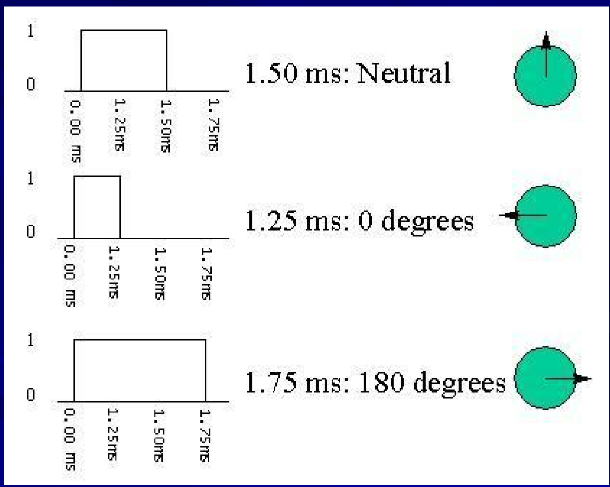
The amount of power applied to the motor is proportional to the distance it needs to travel. So, if the shaft needs to turn a large distance, the motor will run at full speed. If it needs to turn only a small amount, the motor will run at a slower speed. This is called proportional control.

How do you communicate the angle at which the servo should turn? The control wire is used to communicate the angle. The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse Coded Modulation. The servo expects to see a pulse every 20 milliseconds (.02 seconds). The length of the pulse will determine how far the motor turns. A 1.5 millisecond pulse, for example, will make the motor turn to the 90 degree position (often called the neutral position). If the pulse is shorter than 1.5 ms, then the motor will turn the shaft to closer to 0 degrees. If the pulse is longer than 1.5ms, the shaft turns closer to 180 degrees.

As you can see in the picture, the duration of the pulse dictates the angle of the output shaft (shown as the green circle with the arrow). Note that the times here are illustrative and the actual timings depend on the motor manufacturer. The principle, however, is the same.



Hacking a Servo

This section is going to describe how to take an RC servo and make it into an excellent gear-head motor. The changes are quite easy to do, once you have seen the insides. This modification is known to work quite well on Futaba S-148 servos, which are commonly available.

The theory behind this hack is to make the servo think that the output shaft is always at the 90 degree mark. This is done by removing the feedback sensor, and replacing it with an equivalent circuit that creates the same readings as the sensor being at 90 degrees. Thus, giving it the signal for 0 degrees will cause the motor to turn on full speed in one direction. The signal for 180 degrees will cause the motor to go the other direction. Since the feedback from the output shaft is disconnected, the servo will continue in the appropriate direction as long as the signal remains.

As for the details, there are actually only two modifications to make to the servo.

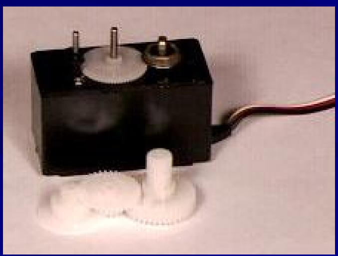
1. Replace the position sensing potentiometer with an equivalent resistor network
2. Remove the mechanical stop from the output shaft

Here are the steps. You will need a few supplies

1. small philips screwdriver for opening the case
2. a soldering iron
3. a desoldering pump or solder wick for removing the potentiometer
4. a sharp knife or wire cutters for removing the mechanical stop
5. Two 2.2k resistors (actually, anything between 2.2k and 3.3k will work, as long as they are equal values)

The following steps will help you make the modifications.

- Open the case by removing the 4 screws located at the bottom of the servo. The bottom plate should come off easily. Remove the top of the case. You will find a set of gears under the top case, a several blobs of white grease. Try hard to save the grease by leaving it on the gears.
- Be careful to note how the gears are arranged, and remove them from the top of the servo. I usually place them as they are supposed to sit. The large fine tooth gear in the middle does not need to be removed. See the picture below.



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- Locate and remove the two small philips head screws on the left shaft in the picture above. These screws go through the top case and into the drive motor.
- Next, you need to remove the circuit board from the case. To do this, you will probably need to press down hard on the brass shaft on the right side. This is the top of the position potentiometer. I find that pressing that brass shaft against the edge of the workbench helps push it through.
- From the bottom, very carefully pry up on opposing corners of the circuit board. The board should slide out with the motor and potentio-meter attached. You should end up with the following parts on the table.

Mechanical Engineering Design

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- Now for the actual modifications. You will need to de-solder the potentiometer from the board. I usually cut the long leads off a quarter inch or so from the bottom. I then use solder wick on the back side of the board.
- Once the pot has been removed, you need to wire in the resistor network in its place. To do this, place the resistors side by side and twist one pair of leads. Solder them together, but leave one of the leads long enough to make a 3 wire part. Then replace the pot with this 3 wire pot. As seen in the picture below, the pot has been replaced by the resistor network. The unmodified unit is on the left, while the right unit was after modification.

Mechanical Engineering Design

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- Now, reassemble the circuit board into the case. Note that the pot is now missing, so only the motor will protrude through the top of the case.
- Before reinstalling the gears, you will need to modify the gear with the output shaft so the mechanical stop is removed. The mechanical stop is a small tab of plastic on the lower gear surface. In the picture below, you can see the tab on the left gear. This should be cut down flush with the surface. Try to get all of the tab removed, as is shown with the gear on the right side.

CS Yee 41

Mechanical Engineering Design

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- Replace the gears as they were when you took the motor apart, replace the top of the case, the bottom plate, and the two screws.
- Your done!

The motor should now be able to turn all the way around. Connect a control horn, and carefully apply enough pressure to make the horn turn around. Feel for any mechanical problems, such as a gear catching on the cut off section of the tab. You should not feel any catching or resistance. It would be best not to play with turning the servo by hand too much. This device is not intended to be driven from the output shaft, and it may cause undo wear and tear on the servo motor.

CS Yee 42

- Replace the gears as they were when you took the motor apart, replace the top of the case, the bottom plate, and the two screws.
- Your done!

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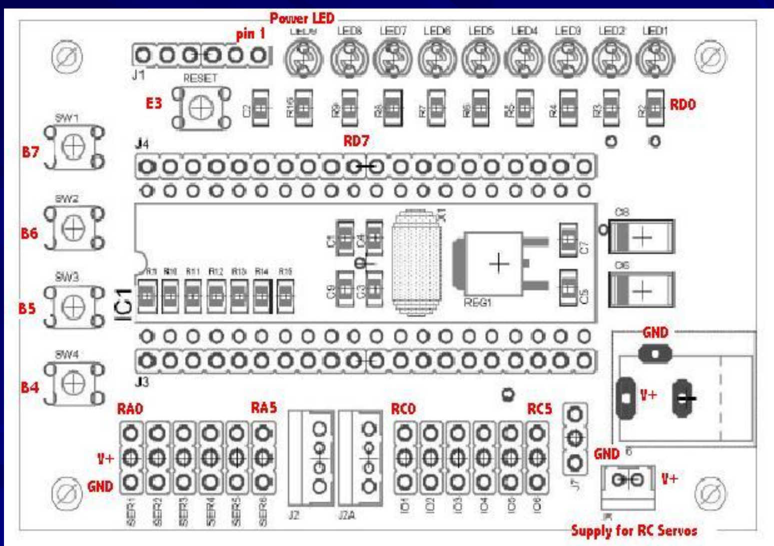
MegaPIC Board



MegaPIC Board Pg. 2

Hardware Specifications

Micro-controller: Microchip PIC18F4520 (40 Pin DIP Package)
Input Voltage: 5.0V to 35V DC
On Board Oscillator: 16MhzMax.
Output Current for Logic Level: 1 Amp
Universal I/Os: 6
RC Servo Connectors: 6
AI-Motor Connectors: 2
User Programmable Push Buttons: 4
Display LEDs: 8
Power On LED: Yes
Reset Circuity: Yes
DC Jack (2.1mm): Yes
Battery Connector: Yes
In-Circuit Programming: PICKIT2 Programmer
Mounting Holes: 4 x 3mm
Board Dimension: 81mm x 53mm

Arduino Leonardo Board Pg. 1

Arduino Leonardo Board

Arduino Leonardo Board

Arduino Leonardo Features

Microcontroller:	**ATmega32u4**
Operating Voltage:	**5V**
Input Voltage:	**7-12V** (limits) 6-20V
Digital I/O Pins	**20**
PWM Channels	**7**
Analog Input Channels	**12**
DC Current per I/O Pin	**40 mA** (for 3.3V Pin 50 mA)
Flash Memory:	**32 KB** (ATmega32u4, 4 KB bootloader)
	SRAM 2.5 KB, EEPROM 1 KB (ATmega32u4)
Clock Speed:	**16 MHz**

Design Project resources

http://guppy.mpe.nus.edu.sg/me3design.html

One-Stop robotics shop

A-Main Objectives Pte Ltd, Block 1 Rochor Road, #02-608, Rochor Centre, S180001, Tel: 63960745

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