Gears Educational Systems, LLC

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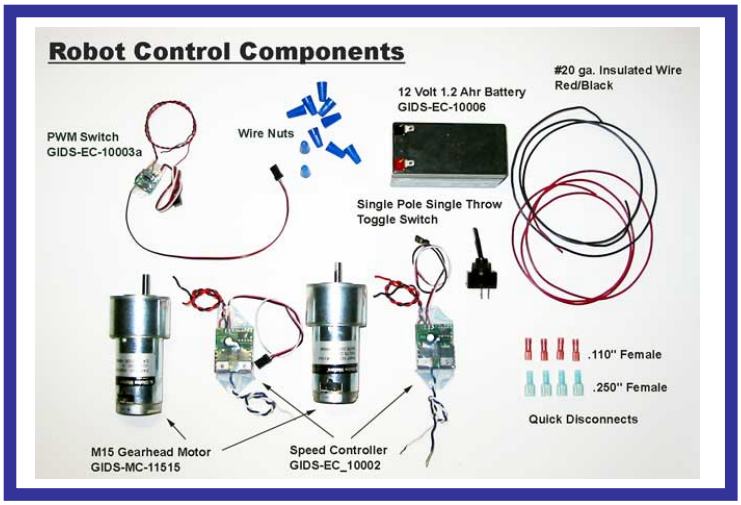
Gears LLC 105 Webster St. Hanover Massachusetts 02339 Tel. 781 878 1512 Fax 781 878 6708 www.gearseds.com

# Configure a Radio Control System

**Configure an RC Control System and Explore These Electronic Engineering Principles:**




**Electrical and Electronic Principles**

- **Electrical Safety**
- The Operation of Electrical Circuits
- The Operation of Electronic Components
- Testing and trouble shooting Electrical Circuits
- Basic Wiring Techniques

**Science and Engineering Principles**

- Electrical Theory
- AC/DC Current
- Series and Parallel Circuits
- Discreet Components and Semiconductors
- Digital and Linear Integrated Circuits
- Volts/Amperes/Resistance/Watts
- Frequency and Pulse Width
- Amp Hour Capacity
- Electronic Measurement

**Design Principles**

- Configuring Circuits
- Wire Ampacities
- Determining Battery Capacity

**Mathematics**

- Ohms Law
- Kirchhoff's voltage Law

**History of Science and Technology**

- Physicists, Chemists and Philosophers that contributed to the science of Electricity and Electronics.

## Programming and Micro Controllers

Use the **GEARS-IDS** Invention and Design System with your favorite Micro Controllers!
The **GEARS-IDS** Electronic Components work well with any micro controllers capable of outputting standard RC PWM (Pulse Width Modulation ) signals.

**Performance Tip.** Before beginning any project, it helps to have a sense of what the beginning, middle and end of the project looks like. For **Best Results Read the Entire Document Before Beginning**

**The RC Control System can be bread boarded in less than 1 hour by a team of 2-3 people. Each person in the group should participate in the activities listed below.**

**Performance Tip.** Engineering is a team sport. Be an engineering MVP. **Accept and commit to completing specific responsibilities.**

1. **Obtain and organize the Tools and Materials** *(Listed below)*
2. **Wire one or more of the electrical subassemblies** *(Illustrated in this document)*
3. **Breadboard the Components and create a working 3-4 channel RC Control System.**
4. **Collect, organize and carefully store the Materials Tools and Equipment at the appropriate times.**

## Tools

Safety Glasses
2-3pt. Phillips Head Screwdrivers
Wire Strippers and Cutters
Wire Crimps
6" Needle Nose Pliers
Multimeter (Optional)

## Electrical/Electronic Components and Hardware

**Electrical/Electronic Components**

2 M15 Gear head Motors GIDS-MC-11515
2 Speed Controllers GIDS-EC-10002
1 PWM Switch GIDS-EC-10003a
1 SLA 12 volt, 1.2 Amp. Hour Battery
1 "Intelligent" 12V Battery Charger
1 Single Pole Single Throw Toggle Switch (SPST)

**Radio Equipment**

1 RC Hobby FM Transmitter (75mhz. /4 ch.)
1 RC Hobby Receiver (75mhz.)

**Hardware**

Assorted Wire Nuts
4' #20 ga. Black Stranded Wire
4' #20 ga. Red Stranded Wire
4-8 #18-22 ga. .110" Female Quick Disconnects fully insulated
4-8 #18-22 ga. .250" Female Quick Disconnects fully insulated
Vinyl Electrical Tape
6" Zip Ties

**NOTE: The GEARS-IDS Electronic Components will operate with any standard AM or FM hobby Radio System. They are not designed for use with PCM Radio Systems. Operating any of the GEARS-IDS electronic components with PCM radio systems is inadvisable.**



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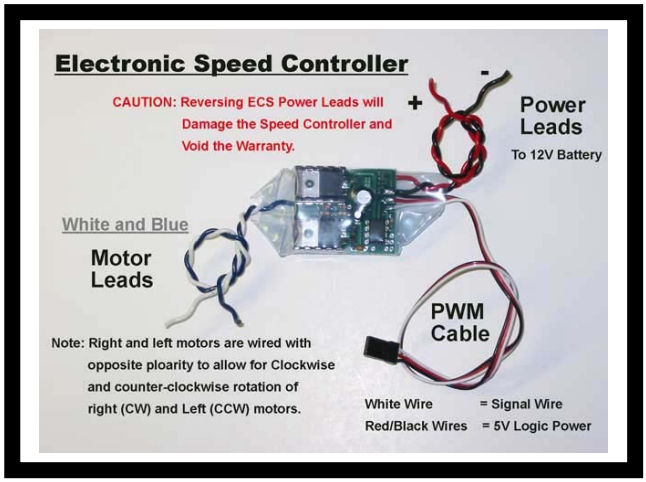
# Configure a Radio Control System by Following These Steps:

1. **Identify the Components and Their Specifications.**
2. **Make up the Motor Leads**
3. **Make Up Battery and Switch Leads**
4. **Wire and Strain Relieve 2 Motors**
5. **Connect the Battery and Switch**
6. **Making Connections Using Wire Nuts**
7. **Set up and Test the RC Control System**

## Step1: Identify the Components and Their Specifications


### Gear Head Motor GIDS-MC-11515

**Spur Gear Transmission:** 19.66 :1 Ratio
**Continuous Torque:** 72 oz. in @ 200RPM
**Current at Rated Torque:** 2.0 amperes
**No load speed at 12 Volts:** 250 RPM
**No load current**: 0.4 ampere
**Stall Current:** 6.0 amperes




### Speed Controller GIDS-EC-1002

Fwd/Rev. With Battery Eliminator Circuit (BEC)
**Control Signal:** Standard RC Type PWM
(Pulse Width Modulation)
**Operating Voltage:** 12-15 Volts DC
**Max Current:** 6 Amperes Continuous
**Power Connector:** Bare Lead
**Signal Connector:** Standard 3 wire PWM cable.
**Typical application:** Power (1) M15 Motor
**Weight:** 0.050 lbs



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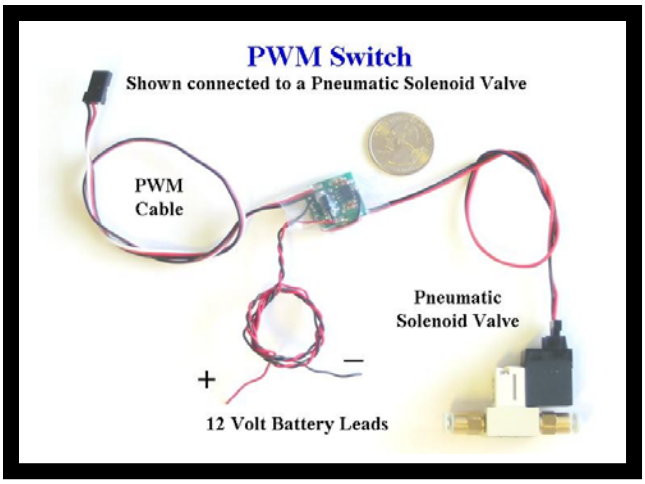
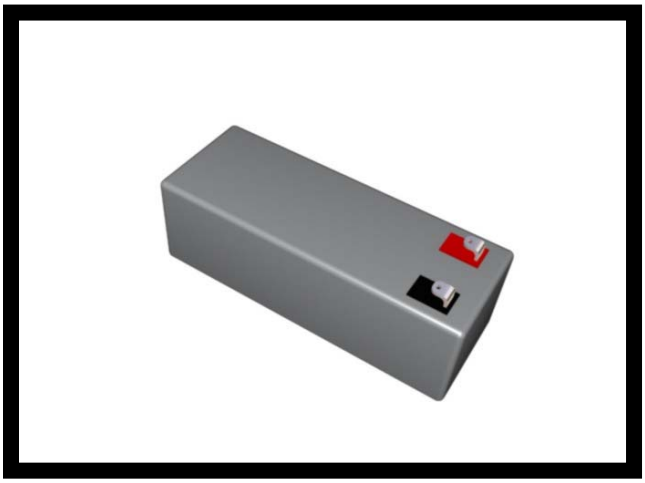



## PWM Switch GIDS-EC-10003a

Fwd/Rev. RC Switch
Caution: Use this switch to power the pneumatic solenoid valve only!
**Control Signal:** Standard RC Type PWM (Pulse Width Modulation)
**Operating Voltage:** 12-15 Volts DC
**Max Current:** 500 milliampere Continuous
**Power Connector:** Bare Lead
**Signal Connector:** Standard 3 wire PWM cable.
**Typical application:** Power 1 Pneumatic Solenoid.
**Weight:** 0.020 lbs



## SLA Battery

Sealed Lead Acid Battery
**Nominal Voltage:** 12 Volts
**Rated Capacity:** 1.2 Amp. Hrs. @ 20hrs.
**Size:** 1-3/4" x 2-1/8" x 3-7/8"
**Weight:** 1.3 Lbs

## Think About This

The 12 volt SLA battery provides the electrical energy to power the motors and the pneumatic solenoids. This energy, produced through a chemical reaction within the battery, is a finite resource. Students who accept the challenge of designing and building an Electro-Mechanical Athlete, must make optimal use of this finite resource.

**Knowledge and Information are Advantages in Engineering Competitions**
The limited amount of electrical energy that can be obtained from the battery is an engineering constraint placed on every competing group. The ability to efficiently use finite energy resources depends in great part on how accurately we can determine:

- The amount of available electrical energy (Battery capacity).
- The energy requirements of the electrical components used on the machine.

In order to determine the amounts of available energy, and the energy requirements of the electrical components, we need to answer these questions:

- **How much usable energy can the battery produce and at what rate can the battery supply energy before it is effectively "Exhausted".**
- **How much energy do the motors and other electrical components require during "Normal loading" operation, and how can this be determined?**
- **How long will the motors and other electrical components operate under normal loading given the amount of available energy in the Battery?**

Designers and Engineers use three different methods to answer questions like these:

| | |
|---|---|
| Estimates | (Informed guesses based on knowledge and experience) |
| Mathematical Models | (Theoretical approximations based on known values and the mathematical relationship between those values.) |
| Actual Tests | (Formal and informal experiments) |

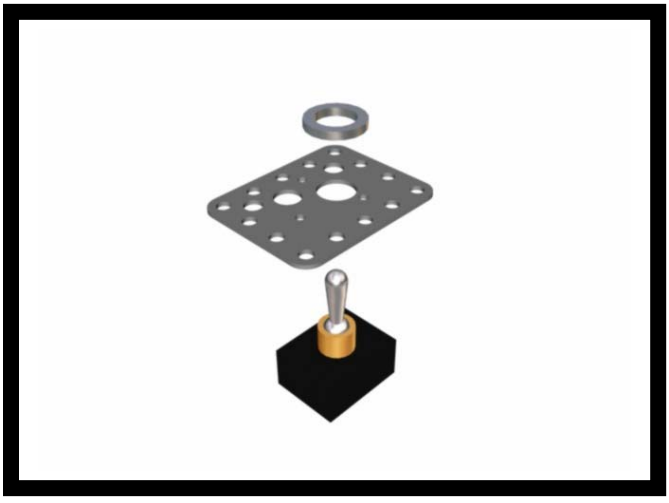
## 12 Volt SLA Battery Charger

(Sealed Lead Acid) **GIDS-EC-10006BC**

A Microprocessor controlled charger that monitors the battery's charge state and regulates the charging current accordingly. This prevents overcharging and maximizes battery life.

This charger is fitted with insulated (black/red) alligator clip leads. This charger can be used with a variety of SLA batteries with rated capacities between .75 and 2.5 Amp hours.

## Single Pole Single Throw Toggle Switch (SPST)

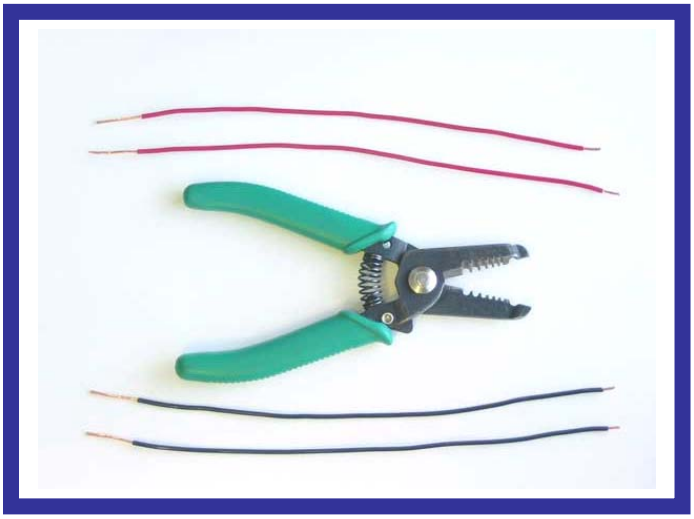


The SPST Toggle switch is shown being assembled to the the IM 13 motor mount which doubles as a switch plate.

This switch is used as the main power switch for the control system.

# Step 2: Make Up the Motor Leads

Learn to use basic wiring tools and Solderless connectors.

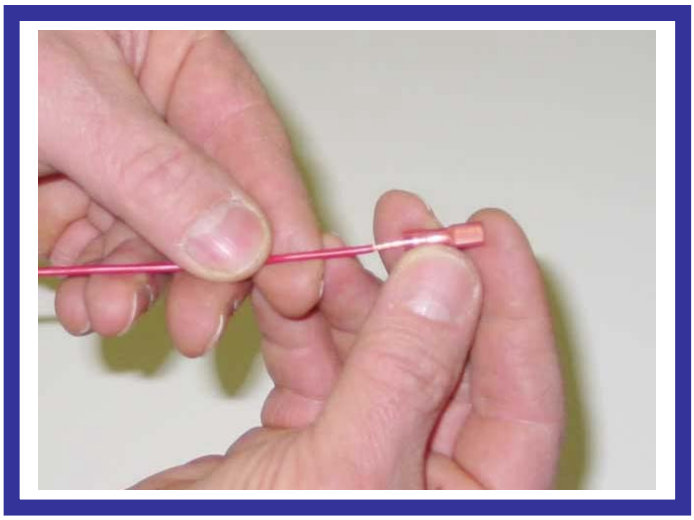


## Wire Striping

1. Cut 2  8-10” Lengths of Red # 20 Ga. Wire.
2. Cut 2  8-10” Lengths of Red # 20 Ga. Wire.
3. Strip off ¼” of insulation from the end of each wire
4. Strip off 1” of insulation form the remaining end of each wire.

Note: The .110” (smaller) Solderless connectors are attached to the ¼” stripped end.

Note: The cutting teeth of the wire strippers are marked with the gage numbers of the wires they are designed to strip. Use the appropriate size cutting teeth for the wires being stripped. Typically 18-22 gage.

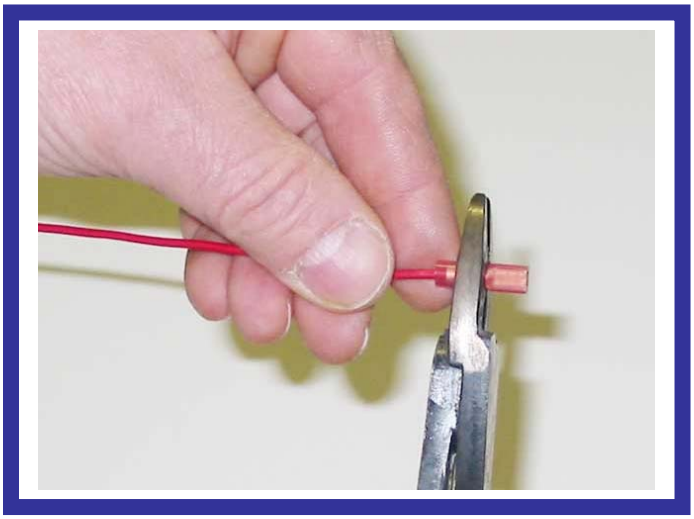


## Attaching Solderless Connectors

**Tool Tip:** Examine the Quick Disconnect closely. Note that this Solderless connector is comprised of  a metal connector housed in a plastic insulated jacket. One end of the metal connector is designed to mate to the spade terminals of the battery. The other, barreled end, is designed to be crimped to a ¼” stripped wire lead. Note the seam on the tubular section of the metal connector.

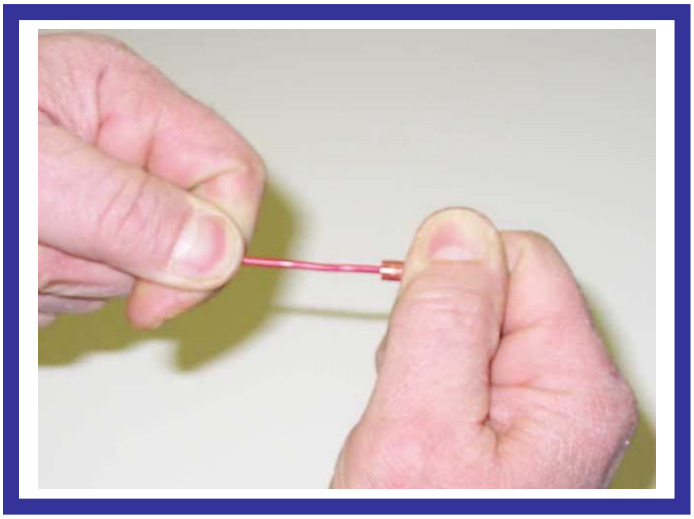
Examine the wire crimping tool. Note that this tool works like a pair of pliers. The Solderless connector is affixed to the wire by crushing the barreled end of the connector around the stripped wire lead. Note that the 2 jaws of the crimping tool are different. One jaw has a tooth form while the other jaw is semi-circular shaped. Take care to always align the seam of the metal connector with the tooth form of the wire crimping tool. This will help ensure consistently tight connections

## Crimping the Connectors



1. Fit the connector to the ¼” stripped wire end. Be certain that the wire insulation butts tightly to the metal barrel of the connector.
2. Hold the wire and connector in position with one hand and grasp the crimping tool with the other hand. Note: This takes a bit of practice, and can feel uncomfortable the first few times you do it. Like many jobs, it’s often easier to ask a partner for assistance.
3. Position the wire, and connector in the jaws of the crimping tool as explained previously. Squeeze the handles of the crimping tool firmly. You will feel the barrel end of the connector being crushed around the wire lead. If you squeeze too tight, you can force the tooth of the crimping tool to puncture the barrel of the connector. This will cause the connection to fail prematurely. If this happens, cut the wire connector off and repeat the procedure.

## Test the Connection



Develop the habit of testing every connection you make.

Grasp the wire in one hand and the connector in the other as shown. Pull firmly on both ends. The connection should be strong enough to withstand your hardest pull. If the connection breaks, chances are the wire strands were crushed and cut during crimping (Too much crimping pressure) or the wire lead simply pulled free of the connector barrel (Insufficient crimping pressure).

**Repeat this procedure for each of the 4 motor leads.**



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# Step3: Make Up Battery and Switch Leads

Learn to use basic wiring tools and Solderless connectors.

**Required Materials:**

Red/Black #20 ga. Wire
4 Fully Insulated Female Quick Disconnects .250" (Larger)
Tape Measure or Ruler
Wire Strippers
Wire Crimps

## Wire Striping

1. Cut 2 8-10" Lengths of Red # 20 Ga. Wire.
2. Cut 1 8-10" Lengths of Black # 20 Ga. Wire.
3. Strip off ¼" of insulation from the end of one Black and One Red wire.
4. Strip off ¼" of insulation from both ends of one red wire (as Shown)

## Attaching Solderless Connectors

1. Attach (2) .250" female quick disconnects to both ends of one red wire lead.
2. Attach (1) .250" female quick disconnects to the ends of each of the red and black wire leads.

Make up 3 wire leads as shown in the photo on the right.

# Step 4: Wire and Strain Relieve 2 Motors

Learn to use basic wiring tools and Solderless connectors.

**Required Materials:**

Wire Leads (From Step #1)
Vinyl Electrical Tape

6” Zip Ties


## Attach the Wire Leads

Attach one red wire (+) with .110” quick connect and one Black wire (-),with .110” quick connect to each motor post.

Gently bend the attached leads outward and around the motor casing.

Secure the connections with at least 2 wraps of vinyl electrical tape.

Secure the wires to the motor case with 1 six inch zip tie as shown below.

## Strain Relief

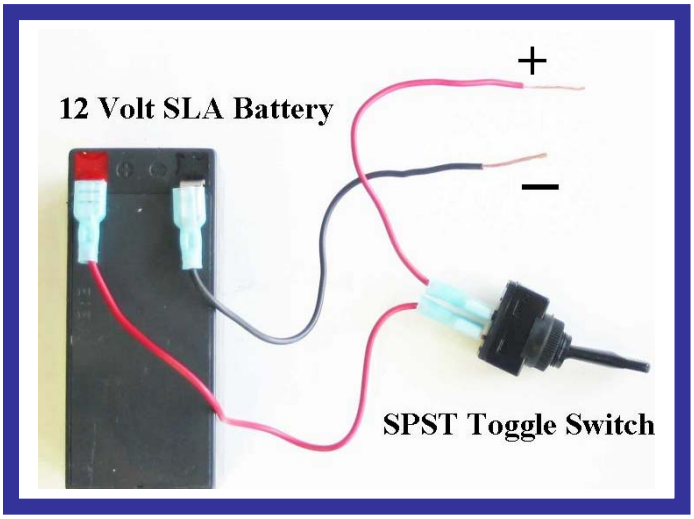
Solderless female quick disconnects provide a good electrical connection but a weak mechanical connection. These connections will fail under the bending and strain that result from normal use. It is necessary to isolate these connections from the normal mechanical forces that result from the normal tugging and pulling on the motor leads.

# Step 5: Connect the Battery and Switch

**Required Materials:**

Wire Leads (From Step #2)
12 volt SLA Battery

Single Pole Single Throw Toggle Switch




## Attach the Wire Leads

1. Attach one red wire (+) with (2) .250" quick disconnect and one Black wire (-),with (1) .250" quick connect to the battery
2. Attach the red battery lead to the switch.
3. Attach remaining red lead to the switch.

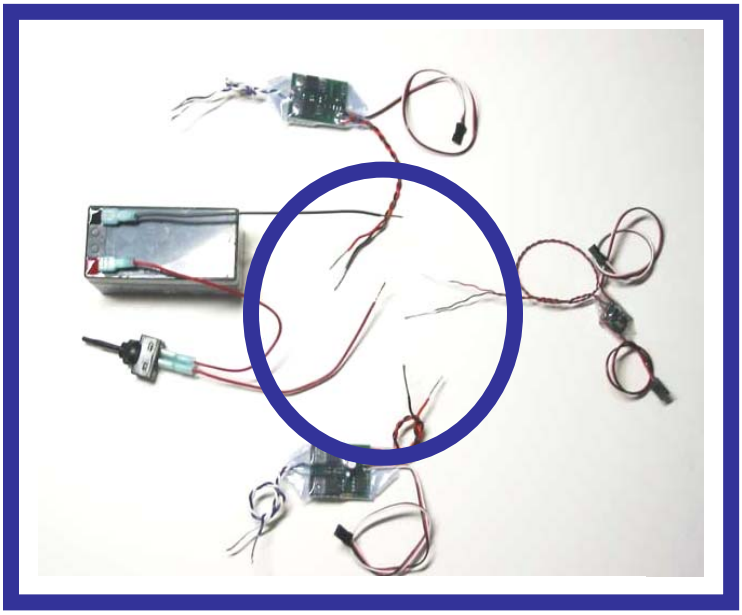
The Set up should look like the picture on the left.

The Positive and negative power leads pictured above provide the main power for the 3 electronic controllers:

1. Left Motor Speed Controller
2. Right Motor Speed Controller
3. PWM Switch used to control the Pneumatic Solenoid Valve

Wiring the remainder of the circuit is simple. Connect the **Red (+)** and **Black (-)** Power leads from each device to the **Red (+)** and **Black (-)** Battery Power leads respectively.

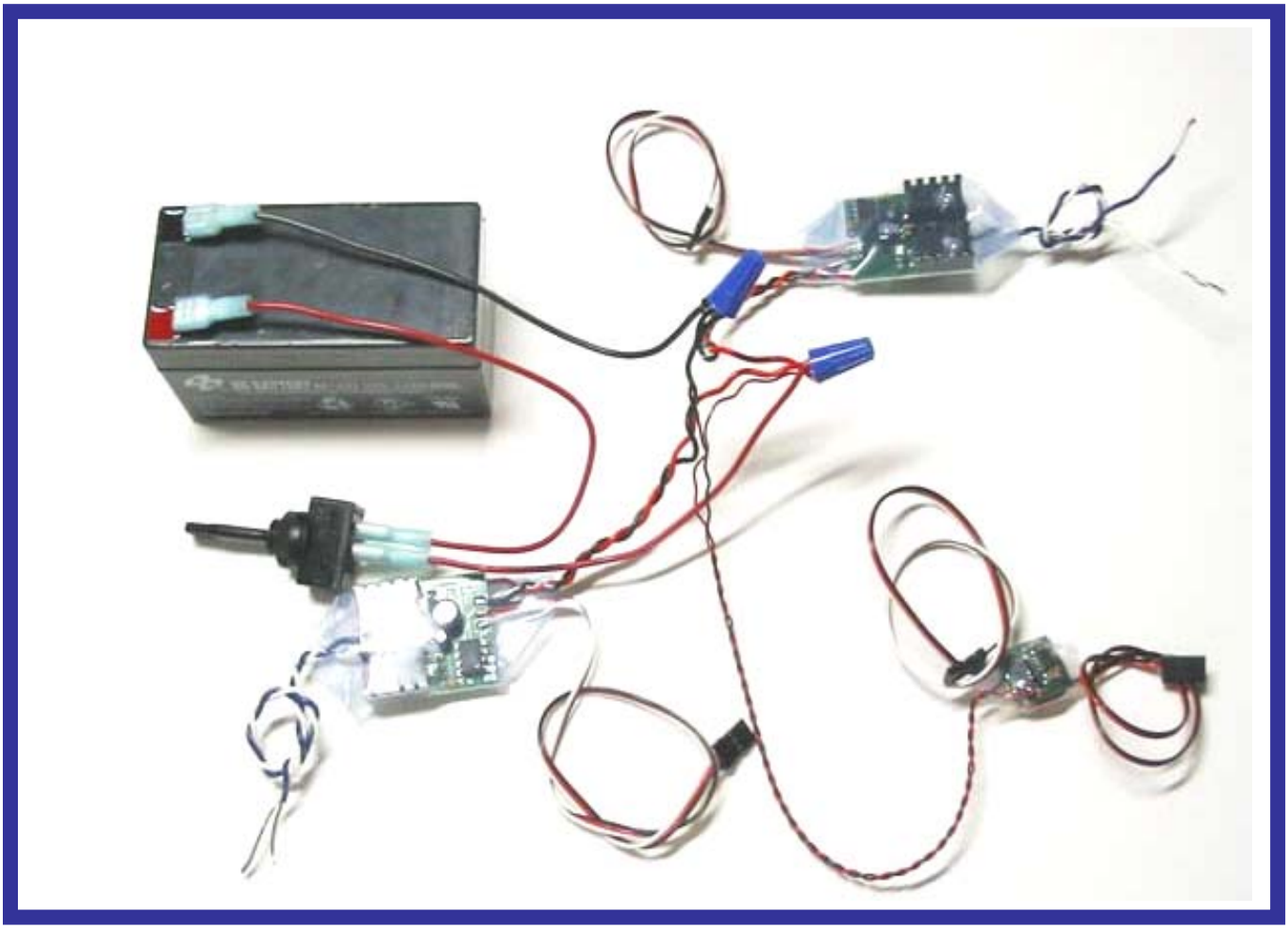
Consult the wiring schematic below for details.



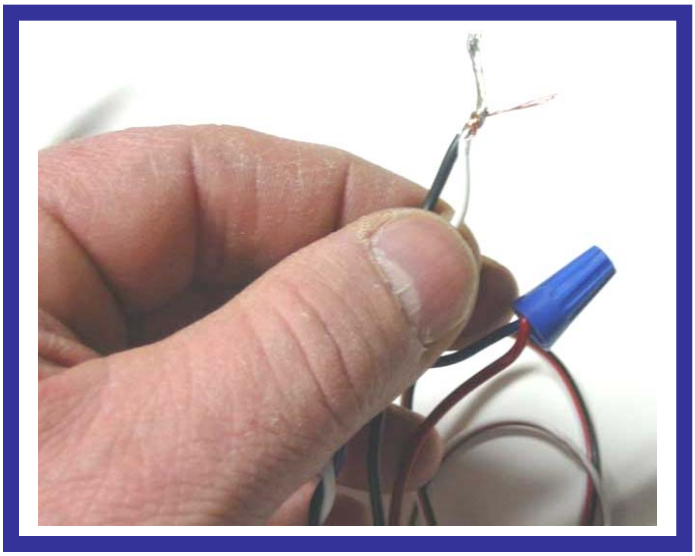
## Connecting the Power Leads

The photograph on the left illustrates the three electronic components in relation to the main battery leads. Identify the **RED (+)** and **BLACK (-)** power leads on each of the components as well as the **RED (+)** and **BLACK (-)** battery leads. The following photograph shows the proper connection.

Caution: Be especially careful when attaching component power leads to the battery. MAKE CERTAIN THE SWITCH IS OFF.
Do not reverse the power leads from the speed controllers or the PWM switch. Even momentary reverse polarity will permanently damage the unit and void the warranty.



# Step 6: Making Connections Using Wire Nuts



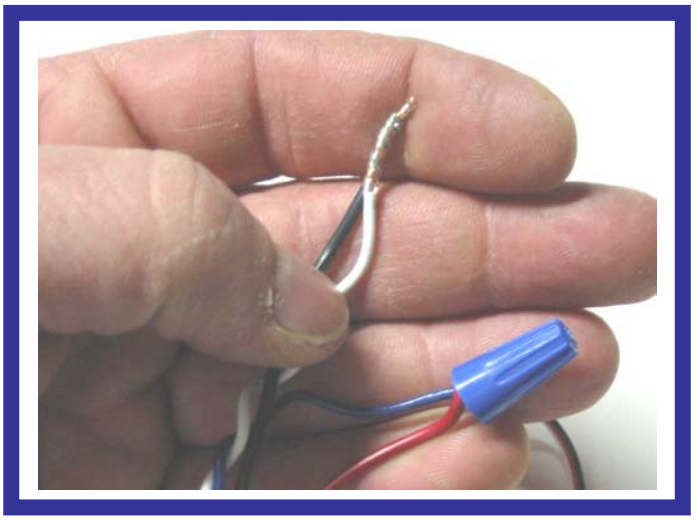
## Use Wire Nuts

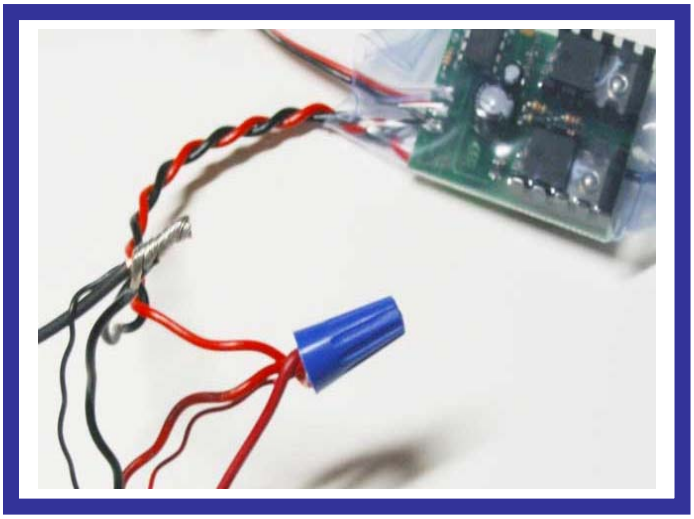
Wire Nuts can be used to quickly and easily connect and disconnect wire leads in a circuit. They are inexpensive and readily available in local hardware stores.

Choose the correct wire nut for the number of wires and gauge size of the wires you are using. ( 2-3 wires, #18-20 gauge)

## Making the Connection

1. Strip ¾" – 1" of insulation off the end of 2, 3 or 4 wires to be connected
2. Twist the wires together tightly. Be careful to twist ALL the wires around each other. The twisted wires should hold together firmly without the aid of a wire nut.
3. Trim the twisted ends to ¾ of the length of the wire nut.



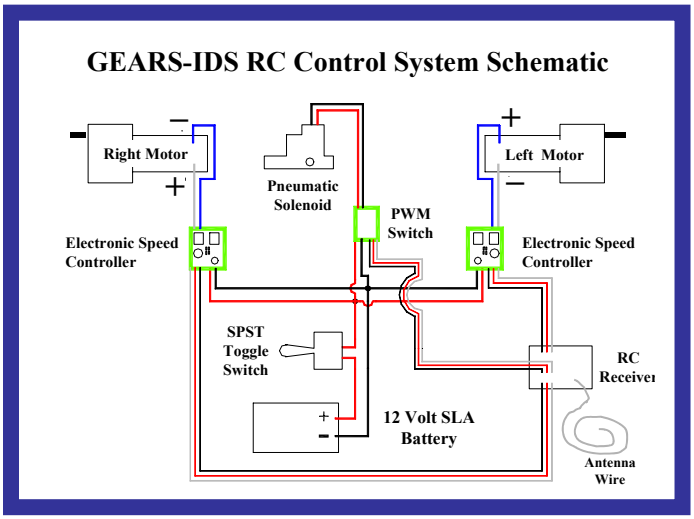


4. Screw the wire nut onto the twisted ends by pushing the nut onto the wire while turning the wire nut clockwise. The wire nut should pull up firmly around the wires. Do not strip out or over tighten the wire nut.
5. The wire insulation should extend well inside the skirt of the wire nut. Do not leave any bare wires exposed. Bare wires will short out on the metal chassis and damage the components.

# Step 7: Set up and Test the RC Control System

**Required Materials:**

1 RC Transmitter
1 RC Receiver
All wires and Leads
1 Pneumatic Solenoid
2 Gear Head Motors GIDS-MC-11515
2 Speed Controllers GIDS-EC-10002
1 PWM Switch GIDS-EC-10003a
1 SLA 12 volt, 1.2 Amp. Hour Battery
1 SPST Toggle Switch



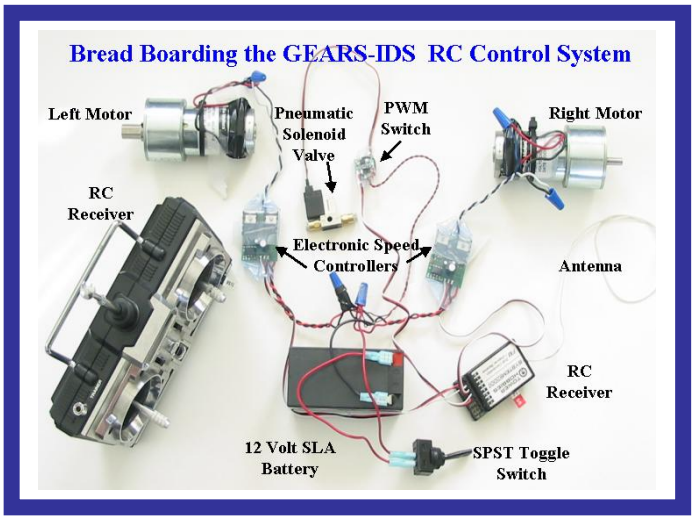

Click on the image to enlarge the picture

## The Circuit Schematic

**Caution: Observe correct polarity when connecting the Speed Controllers and PWM switch to the battery. Reversing the polarity for even a moment will damage these devices and void the warranty.**

Connect the components as shown in the schematic on the left. Use wire nuts to connect the wire leads.

It is best to connect one device at a time and test the operation of that device before wiring the next device.

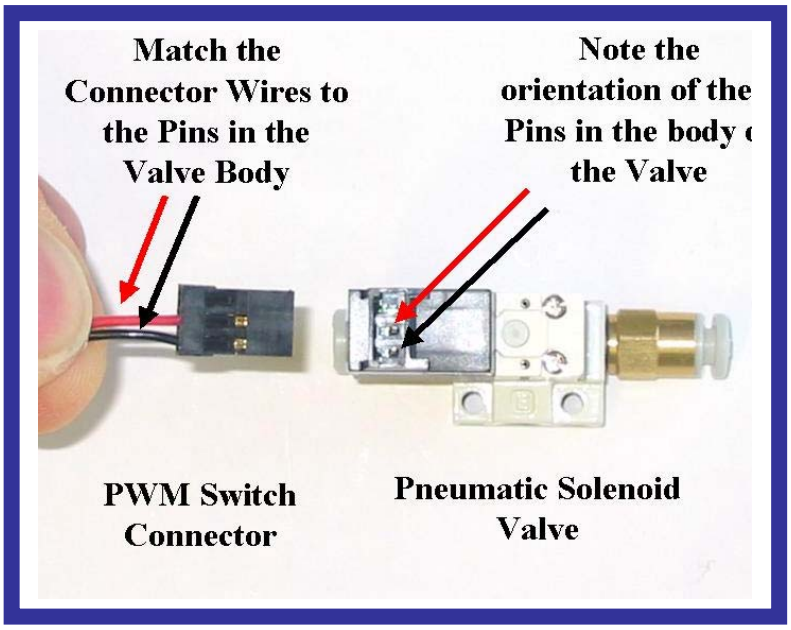



Click on the image to enlarge the picture

## Connect the Motors and Speed Controllers

This photograph shows a completely bread boarded and operable RC control system. This is the same circuit illustrated in the schematic above.

Note: The RED and BLACK motor leads are connected to the WHITE and BLUE Controller Leads. Since the right motor must turn clockwise and the left motor, Counter Clock Wise, the respective leads are reversed.



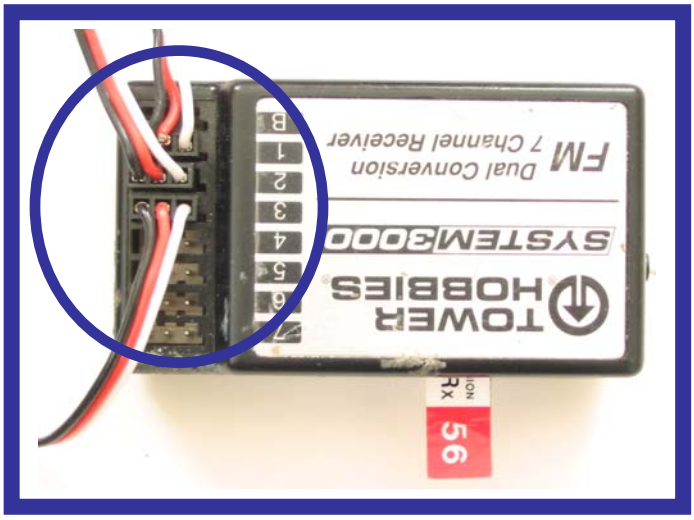

## Connect the PWM Switch to the Pneumatic Solenoid

The power cable from the PWM Switch has only 2 wires, **RED (+)** and **BLACK (-)**.

Caution: The PWM cable of the PWM Switch has 3 wires. Do not attempt to connect the PWM cable to the solenoid valve.

Be careful to align the connector cable wire with the 2 pins inside the body of the pneumatic solenoid valve. It is possible to plug the connector into the valve body 180 degrees opposite of the correct orientation. While this will not harm any components, the valve will not be operable. If the valve fails to operate on start up, check this connection.

Note: It is possible to check the operation of the solenoid valve by watching for the red LED that will light when the valve is turned on.




## The PWM Cables and Receiver Connections

The PWM Cables are made from a 3 wire harness of white, red and black wires.

| | |
|---|---|
| White Wire: | Signal wire from the receiver or a microprocessor. |
| Red Wire: | Positive lead for 5 volt logic current used by the processor on the connected device. |
| Black Wire: | Negative lead for 5 volt logic current used by the processor on the connected device. |

Note: The PWM cables can be connected to the RC Receiver in two ways with respect to the orientation of the 3 pin connector on the end of the PWM cable. The wire color orientation shown in the photograph above is the correct connection. Connecting the cables incorrectly will not harm the connected device or the receiver. The result of an incorrect connection is that the device will not operate.

# Radio Control Basics

The circuit illustrated above utilizes three channels:

1. Right Speed Controller and Motor
2. Left Speed Controller and Motor
3. PWM Switch and Solenoid Controller

The radio system actually provides 4 control channels. This means there is an unused control channel available. This channel could be used to operate one of several devices including lights, additional Electronic Speed Controllers, PWM Switches or Hobby Servos. Hobby servos are particularly useful devices that can be plugged directly into the RC Receiver. While they only rotate thru 60-90 degrees of arc, they have high torques and are useful for operating many different mechanisms including lever systems and linkages, gates, latches and lifting mechanisms.

## One and Two Stick Control

It is possible to configure the RC Control System for one or two stick operation.

**One Stick Operation**

This configuration allows for the control of both motors along both the X and Y axis of the joystick on the right side of the transmitter console.

Plug the PWM cable from the Left and Right motor Speed Controllers into the #1 and #2 channels of the RC Receiver respectively. This configuration will allow the operator to control the speed and direction of the left motor through movements along the Y axis (forward and backward direction) of the Transmitter joystick (right side). The Right motor will be controlled by the X axis (left to right direction) of the Transmitter joystick (right side).

In order to Run both motors in the same direction, it is necessary to move the joystick at a 45 degree angle to either the X, or Y Axis. This can be uncomfortable initially, but operators learn to adapt by re-orienting the position by which they hold the transmitter.

**Two Stick Control**

This configuration allows for the control of both motors along the Y axis both the right and left joysticks on the transmitter console.

Plug the PWM cable from the Left and Right motor Speed Controllers into the #1 and #3 channels of the RC Receiver respectively.

This will allow the operator to control the motion of the left motor through Y axis (forward and backward) motions of the left joystick, and the right motor through Y axis (forward and backward) motions of the right joystick. This reserves X axis motions for the control of other components.



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# System Start Up and Operation

**READ THE RADIO SYSTEM DOCUMENTATION BEFORE OPERATING THE RADIO TRANSMITTER OR RECEIVER**

**RC CONTROLLED MECHANISMS CAN MOVE VIOLENTLY AND WITHOUT WARNING. ALWAYS WEAR SAFETY GLASSES WHEN WORKING ON OR OPERATING ANY MECHANISMS.**

1. **Be certain the radio system you are using tuned to either 27 Mhz, or 75 Mhz**. This is clearly marked on the back of most radios. These are the only frequencies allowed for surface vehicle operation. Do not operate surface based mechanisms using a radio tuned to 72 Mhz. 72 Mhz is reserved ONLY for aircraft. Operating a land based vehicle within range of a flying model can cause damage to the aircraft and or injury as a result of loss of control.

2. Always operate Radio Systems, and the mechanisms they control with **freshly charged batteries.** As the battery voltage drops, the controllers can behave erratically.

3. **Always turn the Transmitter radio on, BEFORE turning on the RC Control System.** The microprocessors in the control system circuits are programmed to "Seek" control signals from the receiver. If the transmitter is not turned on, the control circuits cannot find a signal and they may act uncontrollably as a result. This could mean that motors and pneumatic systems operate uncontrollably and erratically. This could result in injury to anyone near the uncontrolled mechanism.

4. **Be certain the receiver antenna is fully insulated**. Bare antenna wire can ground out on the metal frame and result in loss of control.

5. Bringing the transmitter antenna too close to the receiver antenna can result in erratic and uncontrolled response.