

Constructing a Low-Cost Mobile Eye Tracker

Section 1: Introduction

This is a detailed set of instructions on how to build a low-cost mobile eye-tracking system from off-the-shelf components. Below is a list of the parts needed for the system, a list of necessary tools, and a step-by-step construction guide. If you have any questions please e-mail dwinfiel@iastate.edu.

Important safety information

1. You should always wear a grounding wrist strap when handling electronic components to protect them from electrostatic discharge.
2. You should always wear safety glasses when cutting material such as plastic or metal, when cutting or stripping wire, and when soldering.

Parts List

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|------------------------------------|
| 1. Aluminum Wire 14 gauge |
| 2. Aluminum Wire 9 gauge |
| 3. 2 10' DB15 Male to Female cable |

4. 2 Aluminum Project Enclosures(13.3 x 7.6 x 5.4cm)
5. 2 DB15 connectors
6. Fire-I Board Camera (black and white)
7. Fire-I Digital Camera (color)
8. 5.7mm lens OR 12.0mm telephoto lens (eye lenses)
9. 1.9mm wide angle lens OR 3.6mm medium angle lens (scene lenses)
10. 17mm M12x0.5 Lens holder
11. 13.5mm M12x0.5 Lens holder 13.5mm
12. 940nm Infrared LED
13. 4 14 pin dip sockets (do not use low profile sockets)
14. 33 Ohm Resistor (0.75W or greater)
15. Safety Glasses
16. USB connector
17. Zip Ties
18. Standard Rosin-Core Solder
19. Electrical Tape
20. Plastic CD case
21. Nylon Spacers
22. 8 Screws 2-56 x 1/2
23. Wratten IR Filter
24. Shrink wrap tubing
25. 2 DB9 connectors

This is the detailed parts listed for the mobile eye tracker.

The following may be purchased from [Radio Shack](#)

Item	Part No.	Price
33 Ohm Resistor	271-1104	\$0.99
14 pin dip socket (4@\$1.20)	900-7243	\$4.80
IR LED	276-143	\$1.79

Aluminum Project Enclosures(2@\$2.99)	270-238	\$5.98
Electrical Tape	64-2375	\$3.19
Solder	64-009	\$8.39
Heat Shring Tubbing	278-1627	\$2.39

The following may be purchased from [9th Tee Enterprises](#)

Item	Part No.	Price
Zip Ties	ZIPTIEASST1000	\$11.55

The following may be purchased from [RAM electronics](#)

Item	Part No.	Price
10' Cable, DB15 Male to Female (2@\$7.95)	MEM-90072	\$15.90

The following may be purchased from [McMaster-Carr](#)

Item	Part No.	Price
Aluminum Wire (14 gauge, 1/4 lbs coil)	8904K73	\$5.91
Aluminum Wire (9 gauge, 1/4 lbs coil)	8904K75	\$8.89
DB15 Female Connectors (package of 6)	2146T13	\$7.69
DB9 male Connectors (package of 6)	2146T11	\$7.69

The following may be purchased from [unibrain](#)

Item	Part No.	Price
Fire-I Board Camera B/W	2057	\$154.00
Fire-I Digital Camera	2035	\$109
12.0mm Zoom Lens	2041	\$19.95

These items may be purchased from [Marshall Electronics](#)

Item	Part No.	Price
Eye camera lens (5.7mm, 38 deg)	V-4305.7-1.6	\$27.15
Wide Angle Lens (1.9 mm)	V-4301.9-2.0FT	\$38.00

Medium Lens (3.6 mm)	V-4303.6-4	\$27.15
Lens Holder (17 mm)	V-LH3A	\$6.00
Lens Holder (13.5 mm)	V-LH08	\$6.00

These items may be purchased from Lowes hardware store

Item
2-56 x 1/2 Stainless Steel Screws
Nylon Spacers (1/4 long)
Nylon Washers

These items may be purchased from [Edmund Optics](http://www.edmundoptics.com)

Item	Part No.	Price
FILTER WRATTEN IR #87	NT54-518	\$56.00

<http://www.edmundoptics.com/onlinecatalog/DisplayProduct.cfm?productid=1918>

Required Tools

1. Drill
2. Soldering iron (temperature adjustable to 700 degrees Fahrenheit)
3. Dremel rotary tool (with cutting disk)
4. Set of small screwdrivers.
5. X-acto knife
6. Locking forceps
7. 3/32" drill bit
8. Sandpaper
9. Wire cutters
10. Wire strippers

Section 2: Scene Camera Case

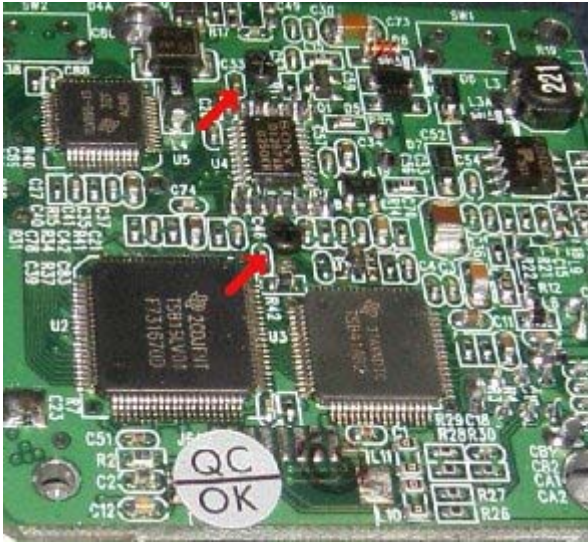
Step 1: Open the case of the color camera.

1. First, it is necessary to find all of the screws (two of the screws are hidden behind the label at the top of the camera).
2. Remove the 4 screws on the back of the camera.
3. Pull the back of the camera case off. The camera board should remain attached to the front of the camera case.
4. There is a small secondary board that is attached to the main camera board. This secondary board plugs into the main board and holds the main camera board to the front of the case. Remove the main camera board by carefully pulling it straight up (away from the front of the camera case).



Step 2: Remove the lens mount

1. On the back of the main camera board there are two screws that go through the board. These screws hold the lens mount to the board. Remove these screws.
2. Remove the lens mount.



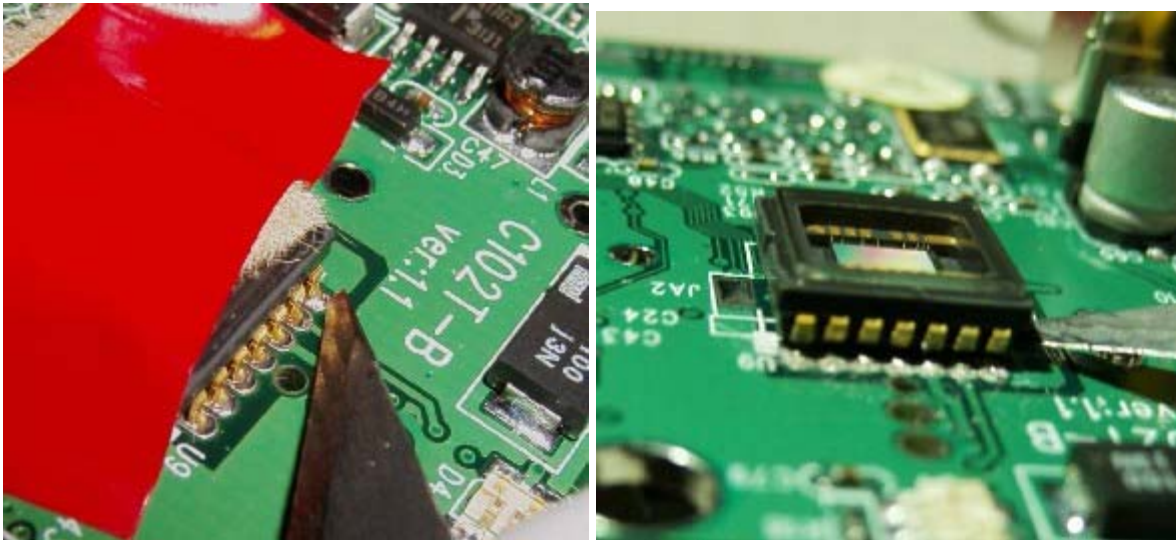
Section 3: Extract the CCD sensor

Note:

- (1) The sensor is cut from the board because it is heat sensitive and will be damaged if it is desoldered from the board.
- (2) This is a delicate process. It is important to be very careful when using the knife because it can easily slip off of the sensor. This could result in damaging the camera board and/or personal injury.
- (3) When doing this you should wear a grounding wrist strap and safety glasses

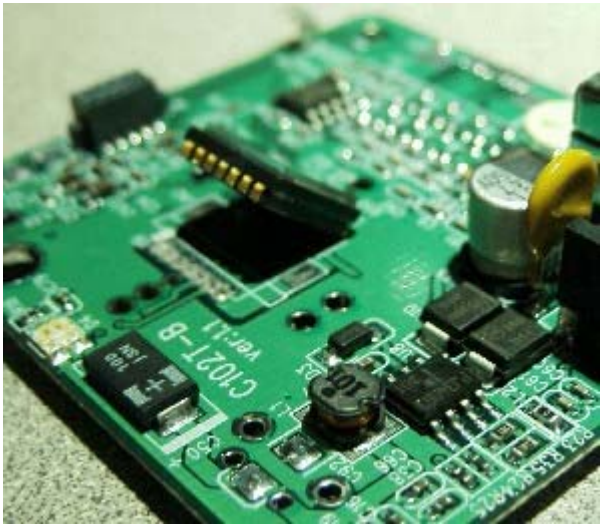
Step 1: Cut the Pins

1. First put some tape over the top surface of the sensor. This will help prevent it from accidental damage.
2. Cut all the way through the pins on one side of the sensor using the Xacto knife. Cut the pins as close as possible to the camera board (it will take awhile to cut all the way through the sensor pins and you must be careful to only cut the pins and not cut the camera board).



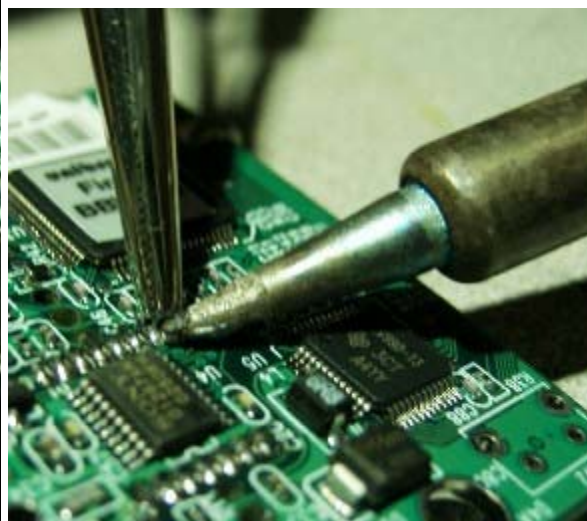
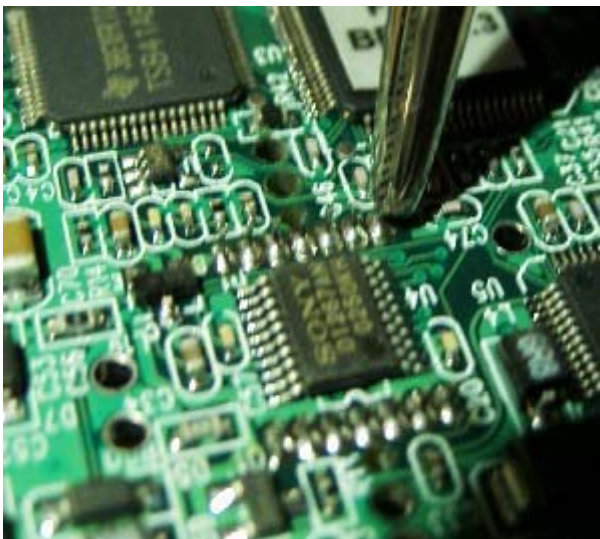
Step 2: Remove the sensor

3. Score the pins on the other side of the sensor a few times with the knife, as close to the camera board as possible without cutting the board.
4. Lift the free side up and down (make sure that the pins bend at the score line) until the pins on the other side break off. They should break on the score line.



Step 3: Remove the pins from the board.

1. First turn on the soldering iron and set the temperature to 700 degrees Fahrenheit. (If you do not have a variable temperature iron use an iron that is 30 Watts).
2. Clamp the locking forceps onto one of the pins (it is easiest to clamp onto the pins from the back of the camera board).
3. Touch the tip of the soldering iron to the pin and pull the pin out with the forceps (make sure not to touch anything else on the board with the soldering iron).
4. Repeat steps 2 and 3 until all of the pins are removed.



Section 4: Camera Enclosure

Note:

- (1) Wear safety glasses when cutting with the Dremel rotary tool.
 - (2) Wear safety glasses when drilling
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Step 1: Mark the locations for cutting

1. Mark one of the sides of the enclosure as shown in the picture below:



Step 2: Cut the holes for the connectors.

1. Cut out the holes, marked in step 1, using a Dremal Rotary Tool.
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Step 3: Mark the locations for screw holes.

1. Place the camera board in the enclosure.
2. Align the connectors on the camera board to the holes in the enclosure
3. Mark the locations of the camera screw holes on the enclosure.

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Step 4: Drill the holes

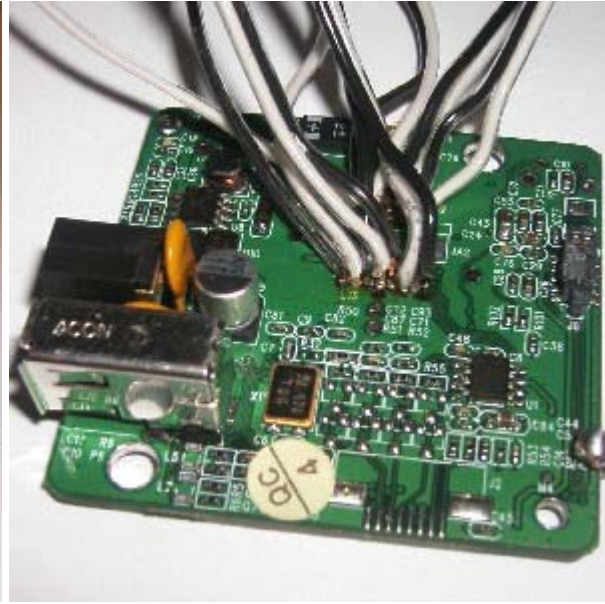
1. Install a 3/32" drill bit into the drill.
 2. Drill the holes, marked in step 3.
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Section 5: Install the Camera Board in the Enclosure

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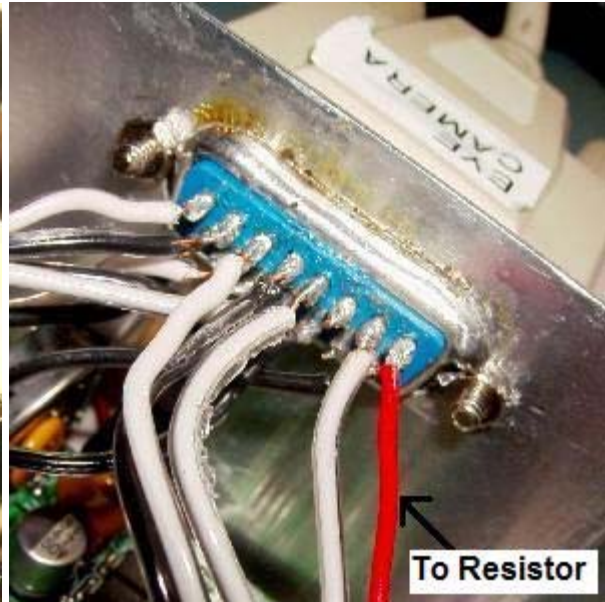
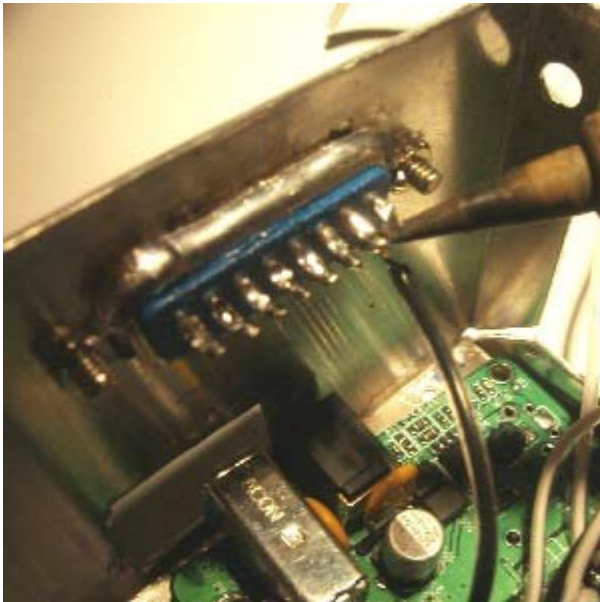
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Step 1: Connect wire to the camera board

1. Measure and cut 14 pieces of solid 24 AWG wire, each approximately 5 inches in length.
2. Strip the end of each wire to about 1/8 inch.
3. Turn on the soldering iron and set the temperature to 700 degrees Fahrenheit.
4. Hold the stripped end of the wire against the hole in the board (where one of the pins was removed).
5. Touch the tip of the soldering iron to the wire. When the wire gets hot enough to melt the solder, push end of the wire all the way through the board (be careful not to burn your fingers when the wire gets hot).
7. Inspect the connection on the back of the board. There should be enough solder left on the board to hold the wire. However, it might require additional solder.
8. Cut off any excess wire that sticks out from the back of the board.
8. Repeat this process for the remaining wires.
9. Check the back of the board to make sure that none of the contacts are shorted together. This can be done easily with a multimeter. (Many multimeters have a continuity checker that will beep if the contacts are connected).



Step 2: Connect the wire to the DB15 pin connector

1. Strip the ends of each of the wires from the camera board
2. Attach each wire to the correct pin on the DB15 pin connector, except for the ground pins (The order is important).
3. The ground pins (pins 6 and 9) should be connected to the enclosure.



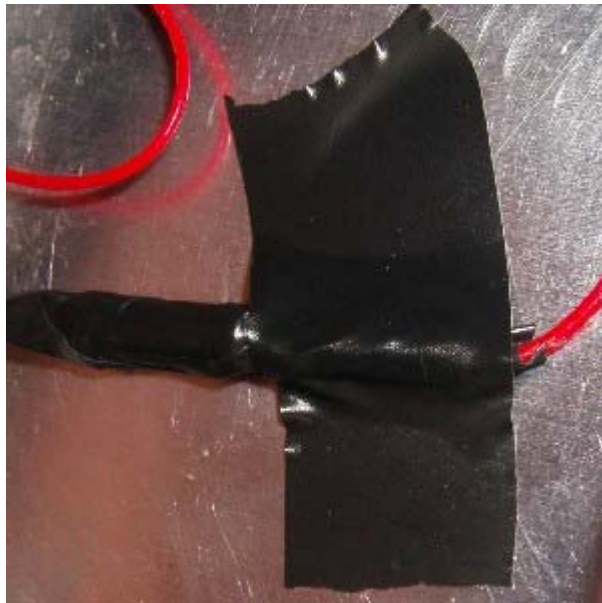
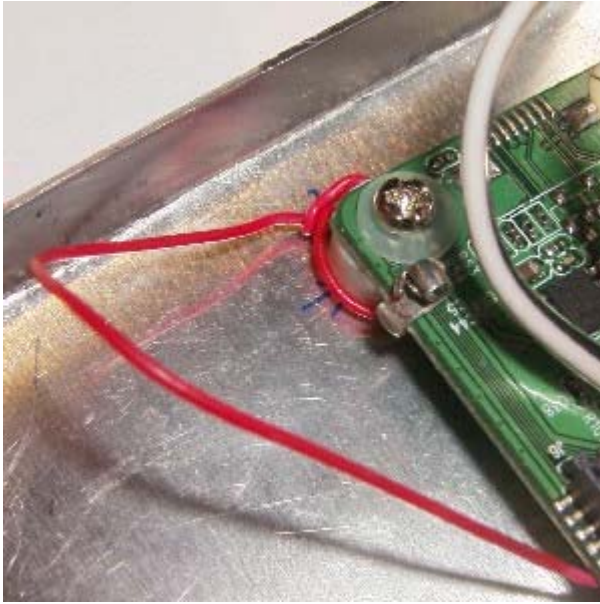
Step 3: Screw the camera board to the enclosure

1. Tap each of the screw holes using one of the screws. The aluminum is soft enough that the screws should tap the holes easily. However, you should work the screws back and forth to make sure that the holes are tapped well.
2. Align the camera board with the screw holes.
3. Place a nylon spacer between the camera board and the enclosure.
4. Align the spacer with one of the screw holes.
5. Insert screw, but do not tighten it down all the way.
6. Repeat steps 3-5 for remaining screws.

Note You may need to file down one or more of the spacers to make the camera board fit correctly.

Step 4: Install a resistor

1. Solder a piece of wire to the top right pin on the DB15 connector (See picture from step 2).
2. Solder the other end of this wire to a 33 Ohm resistor (use 0.75W or greater resistor).
3. Connect the free end of the resistor to another piece of wire (this wire needs to be long enough to connect to a USB connector/cable). It may be useful to have an additional connector between the USB cable and the enclosure.
4. Tie the wire around one of the screws going through the camera board.
5. Run the free end of the wire out of the enclosure (can use the opening from the firewire connector).
6. Place tape around the resistor and tape it to the enclosure.



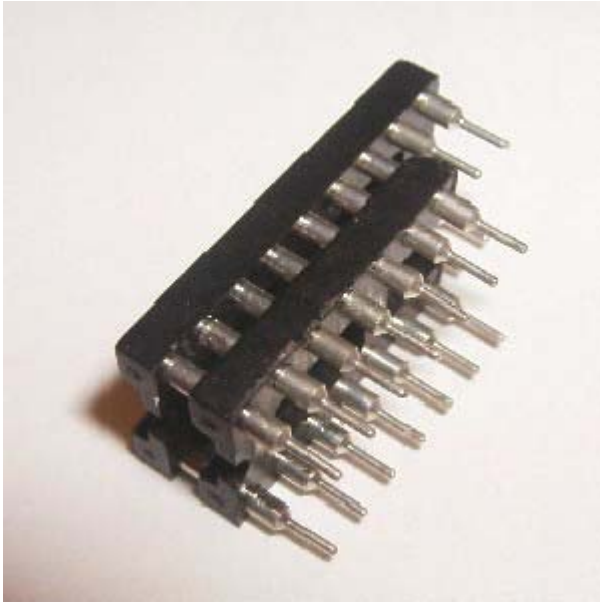
Step 5: Put the enclosure back together



Section 6: Sensor Socket

Step 1: Combine sockets

1. Combine 2 14 pin sockets together (socket on the bottom can have more than 14 pins, the picture is incorrect). This is done to prevent the pins from moving when they get hot.



Step 2: Strip and cut the wires.

Note:

These steps are done to make stripping such small pieces of wire easier. However, there may be better methods for doing this.

1. Use 22AWG solid wire, strip approximately $3/16$ " insulation off of the wire spool.
2. Using the wire strippers cut through the insulation $1/4$ " down the wire (do not remove insulation).
3. Pull the insulation up slightly (approximately $1/8$ ")
4. Cut the piece of wire off the spool, leave both ends stripped. (one to $1/16$ " and one to $1/8$ ")
5. Repeat steps 1-4 until there are 14 pieces of wire (try to make each piece as similar as possible).

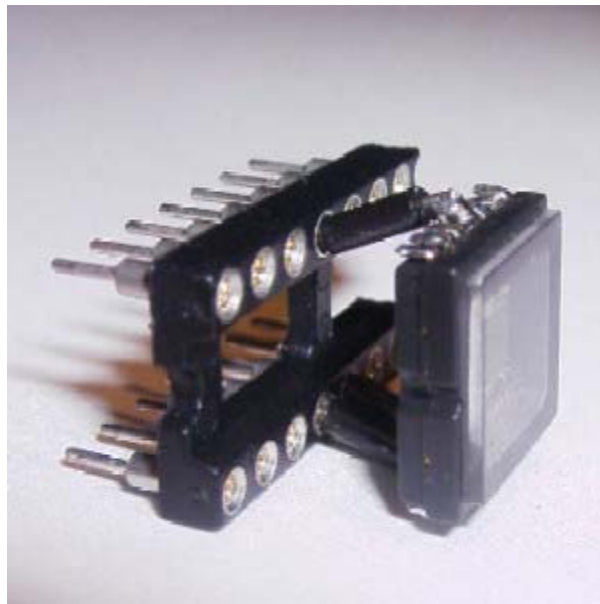
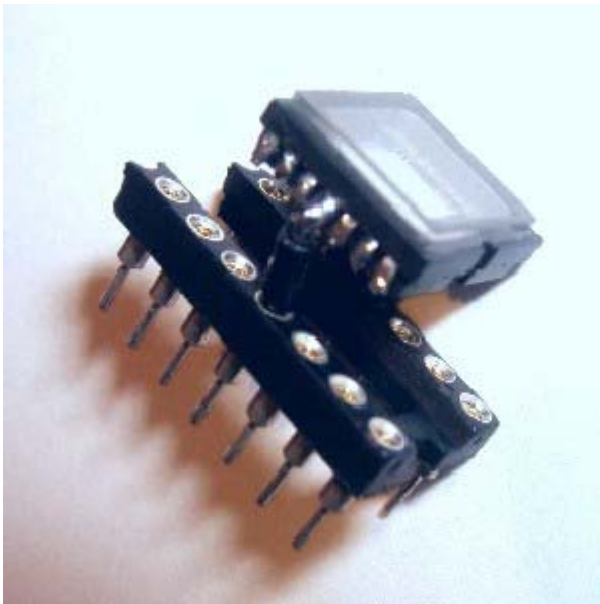
Step 3: Attach the wires

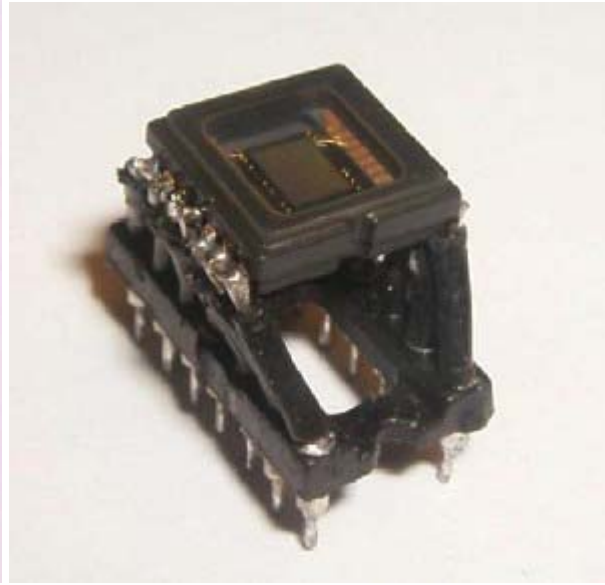
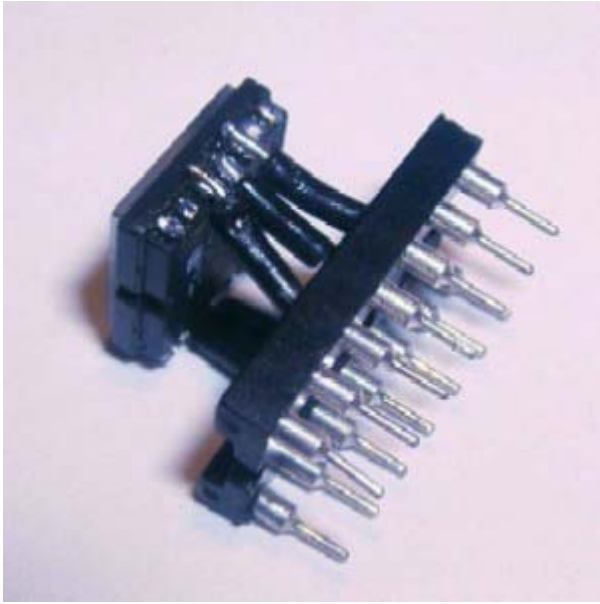
Note:

- (1) This can be a tricky process
 - (2) The length of each wire may need to be adjusted slightly
1. On one side of the socket, insert one of the wires into the middle pin using the side of the wire that is stripped to $1/8$ ". (the wire should fit very tightly in the pin, pliers may be required).
 2. Hold the sensor and socket in place using the helping hands (see

list

- of tools), make sure that pin 1 of the sensor is aligned to pin 1 of the socket.
3. Carefully, solder the free end of the wire to the sensor. Do not leave the soldering iron on the sensor for more than 2 seconds at 700 degrees.
 4. Insert the wire on the opposite side of the socket. It may be required to bend the previous wire outward to make the sensor even on both sides of the socket. Also, make sure the top of the sensor is parallel with the top of the socket.
 5. Solder the wire from #4 to the sensor.
 6. Attach all of the remaining wires in the same fashion, make sure to check the alignment of the sensor. Also, make sure to never leave the soldering iron on the sensor for more than 2 seconds.





Section 7: Eye Camera

Repeat the steps in sections 3-6 that were performed on the color camera to the black and white board level camera (make sure not to mixup the different sensors).



= Section 8: IR filter

Step 1: Cut the filter to size

1. Remove filter from package (be careful not to get many finger prints on it)
2. Cut it to 6mm square



Step 2: Put super glue on lens

1. Add a small amount of super glue around the edge of the lens



Step 3: Add filter to lens

1. Carefully place the filter over the lens.
2. Align the filter so that it covers the glass of the lens.
3. Make sure that the corners of the filter to not sick out. So, they are not in the way of the lens mount.



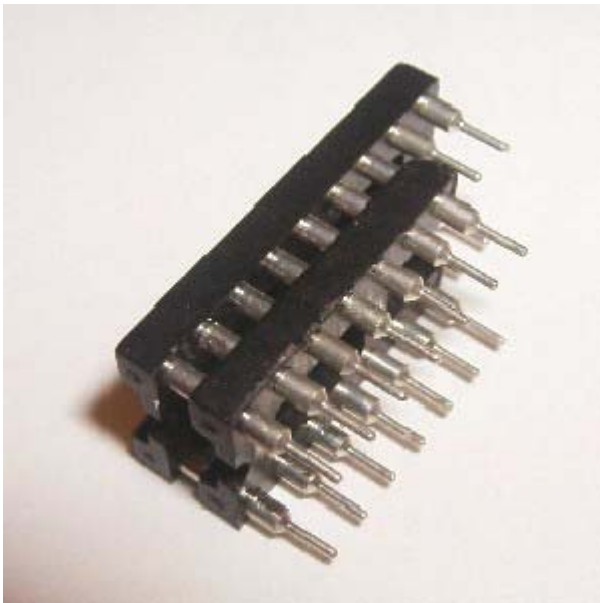
Section 9: Eye Camera Cable

Step 1: Cut cable

1. Cut one of the 15pin cables to 42" in length, the sensor will not work if the cable is too long (use the side with the male connector).
 2. Strip approximately 1.5" of insulation from cable using X-acto knife
 3. Peel back and remove foil sheilding
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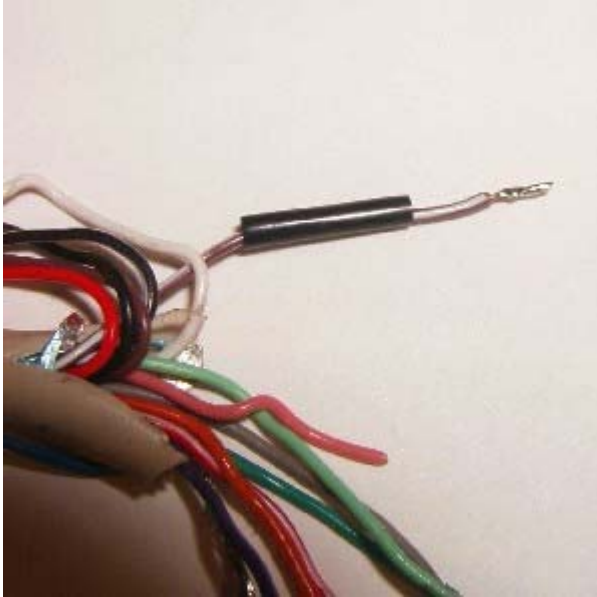
Step 2: Combine two sockets and add solder

1. Push two sockets together. This will help keep the pins from moving around when they get hot.
2. Add solder to each of the pins on the bottom connector.



Step 3: Add shrink wrap

1. Cut 12 pieces of 1/8" shrink wrap to 3/8" in length
2. Slide shrink wrap over the ends of the wires (only wires listed (in the table in step 4)).

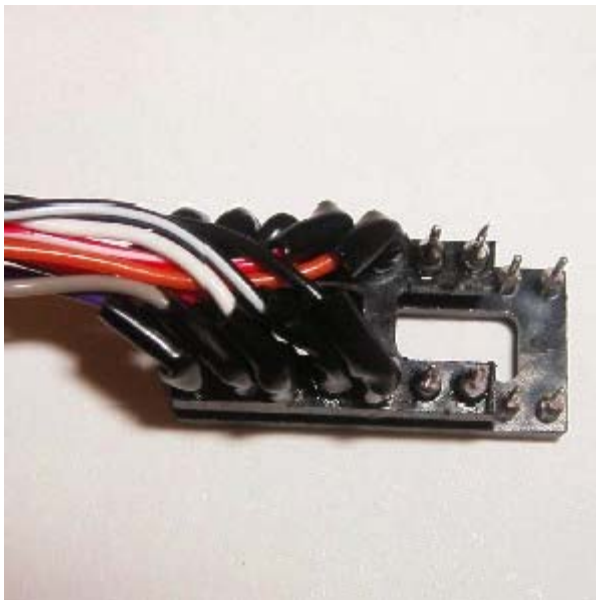
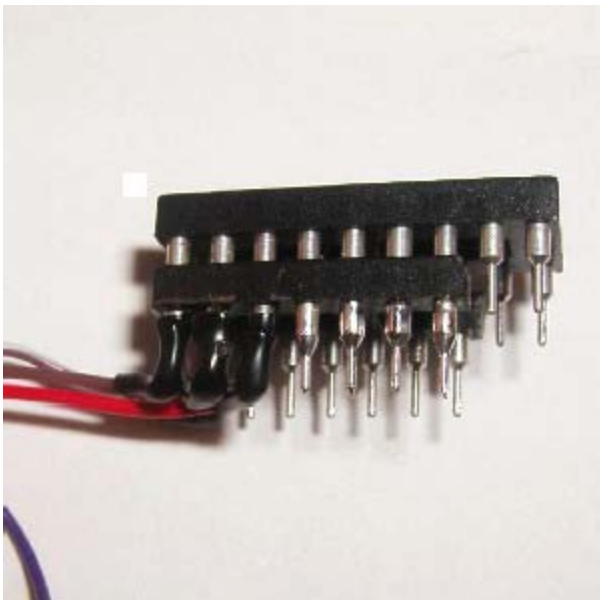
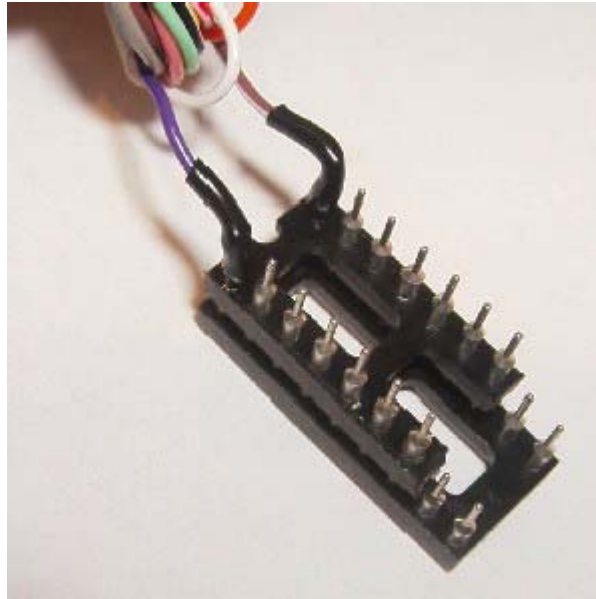


Step 4: Attach wire

1. Attach the wires to the pins on the socket, skipping pins 6 and 9. Start with pins 1 and 14, these wires will need to be shortend. The wires need to get longer as they approach the other end of the socket. The wires need to be bent (see pictures below) so that the cable and socket can be easily mounted on the boom arm.

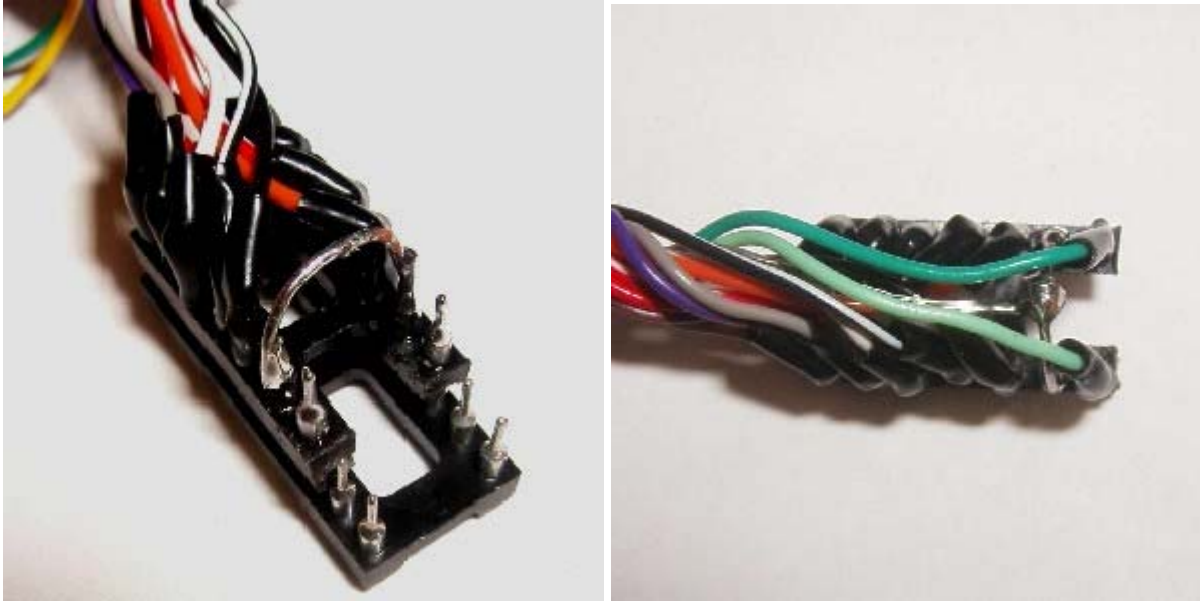
The order of the wires is important			
Pin 1	Brown	Pin 14	Purple
Pin 2	Brown and White	Pin 13	Gray
Pin 3	Red	Pin 12	White
Pin 4	Red and White	Pin 11	Black
Pin 5	Orange	Pin 10	Black and White
Pin 6		Pin 9	
Pin 7	Dark Green	Pin 8	Light Green

2. Slide the shrink wrap over the pins.
3. Heat the shrink wrap with heat gun.



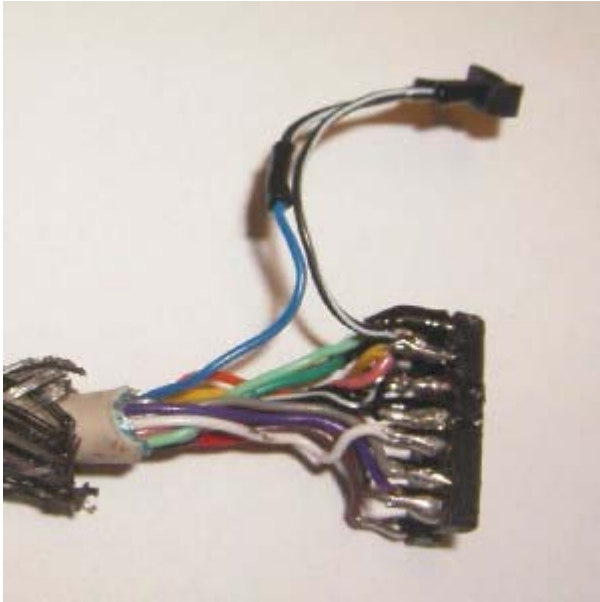
Step 5: Attach ground wire

1. Attach a bare wire between pins 6 and 9.
2. Attach ground wire (the bare wire from the cable) to the wire in #1.



Step 6: LED socket

1. Cut one of the 14 pin sockets (using the x-acto knife), so that there are two pins side by side.
2. Combine the "new" two pin socket made in #1 with another socket to prevent the pins from moving when they are heated.
3. Attach a wire from one side of the two pin socket to the ground wire between pins 6 and 9 (made in step 5)
4. Attach the remaining pin from the two pin socket to the blue wire from the cable.



Section 10: Scene Camera Cable

The scene camera cable is created the same way that the eye camera cable was created. The same order should be used when connecting the wires and the ground.

However, the following changes should be made:

1. No LED is required
2. The cable should not be bent at the socket.



Section 11: Cut the Safety Glasses

Step 1: Draw the pattern on the lens.

Using a permanent marker, trace around the frame of the glasses onto the lens. Leave 1/8 inch of space between the line and the frame of the glasses.



Step 2: Remove the lens from the frame

1. Pull up on the middle of the frame (above the nose piece) while pushing down on the lens. The lens should snap free of the nose piece.
2. Pull the lens down and in front of the snap. The frame should now be behind the lens.
3. Pull the frame down about 1/2 inch from the top of the lens.
4. Remove one side of the lens from the frame by pulling one side of the frame backwards (away from the lens).

Step 3: Cut the lens

Note For this step it is recommended that a Dremal Rotary Tool is used instead of a coping saw.

1. Securely clamp the lens from the safety glasses.
2. Using a coping saw or a Dremal Rotary Tool cut along the lines from step 2.



Step 4: Sand the edges

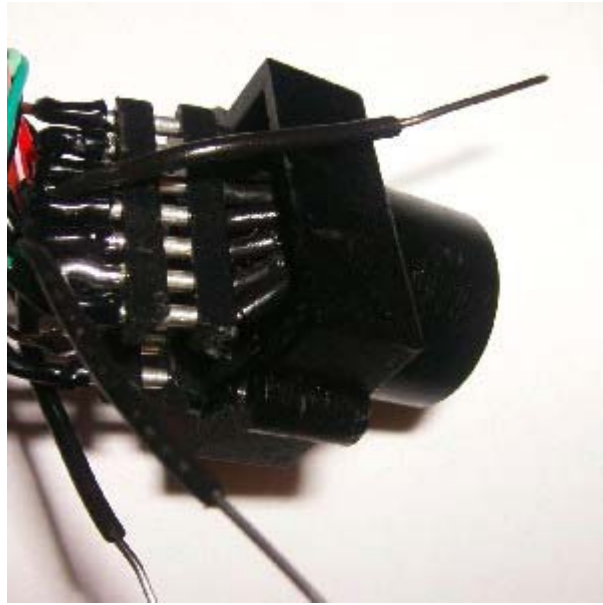
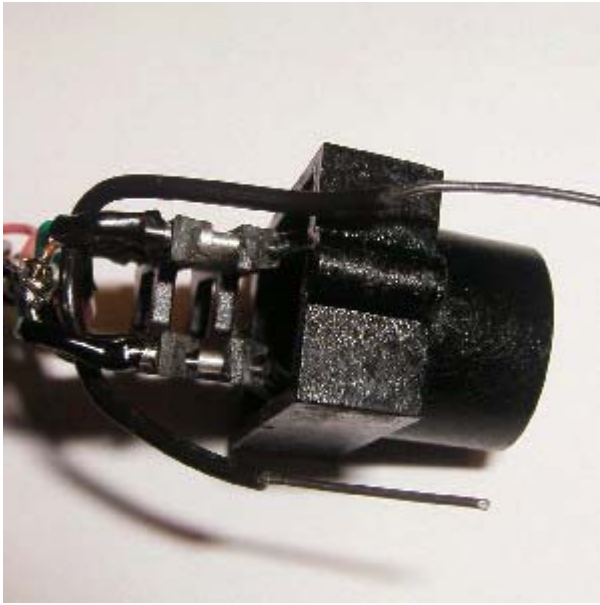
Sand the edges of the lens to make sure that there are no sharp places where the user may be cut on the plastic. The surface of the lens may also be sanded so the plastic is not clear.

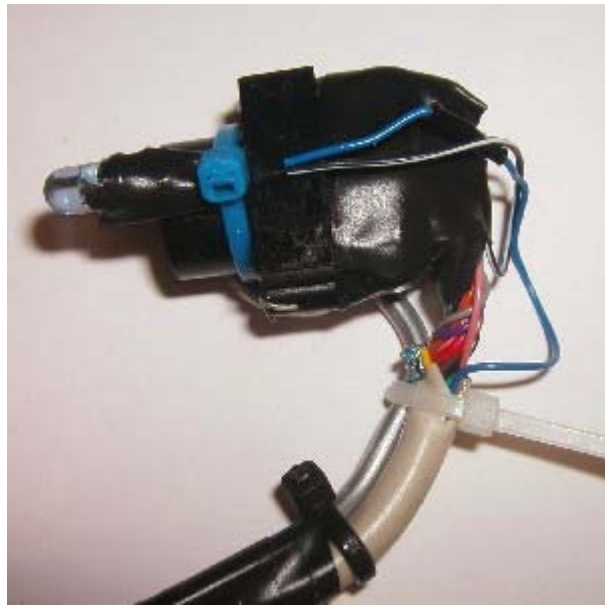
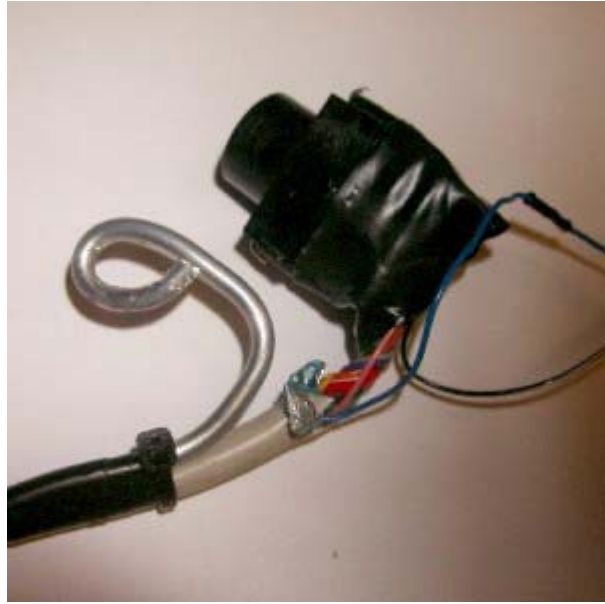
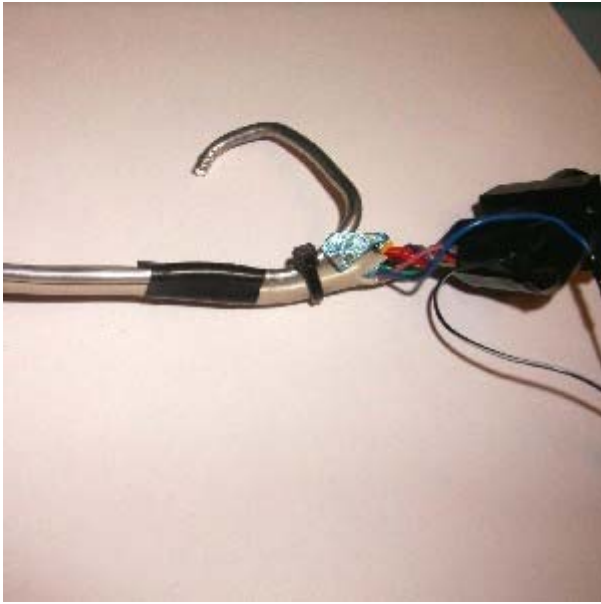
Step 5: Replace the lens.

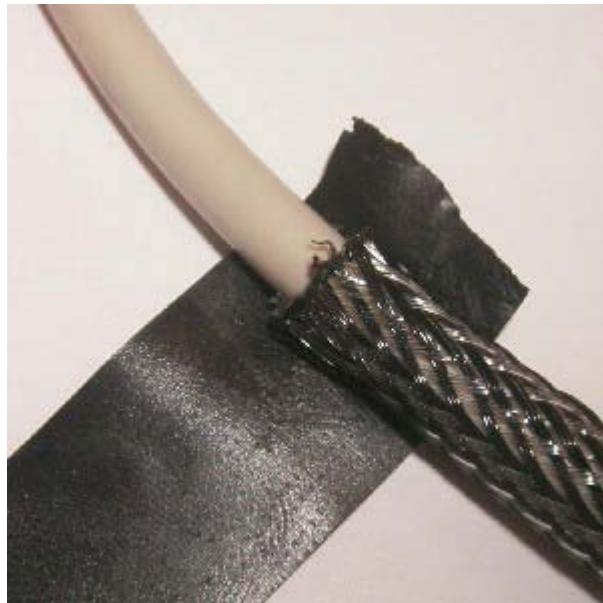
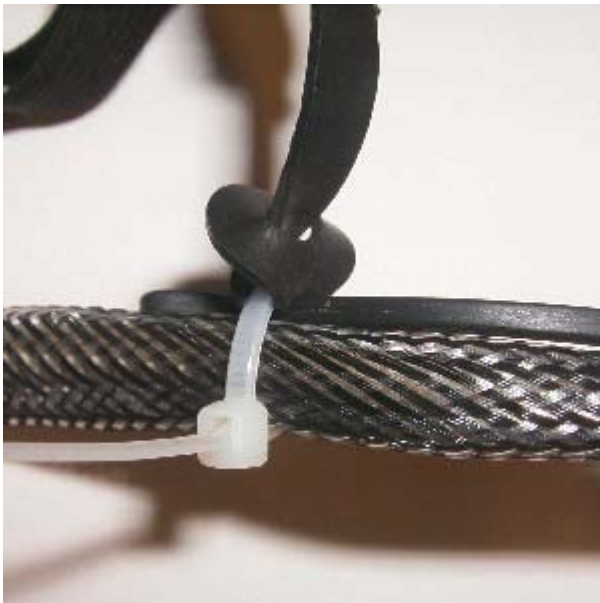
The lens is replaced by reversing the steps that were followed when removing the lens.



Section 12: Mount the Eye Camera







Section 13: Mount the Scene Camera



The Completed System



(a)



(b)

