Turbidity Sensor Construction Documentation

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EE 4951W

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Enclosure Assembly

Parts Required:

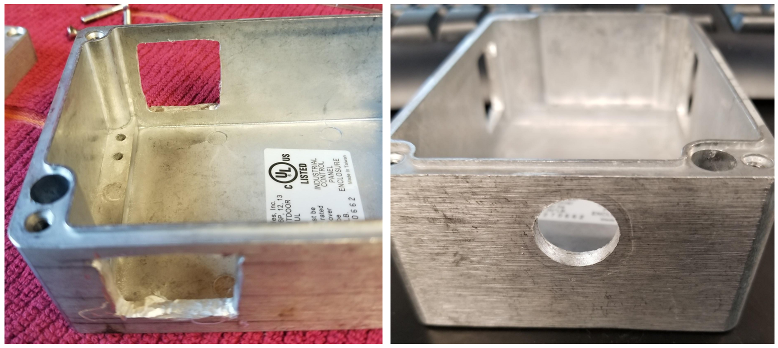
- Polycase AN-14P Aluminum Box

Tools Required:

- Dremel or other small metal cutting saw
- Power drill or drill press
- Vice
- Ruler
- Pencil
- Phillips Screwdriver
- Compressed air
- Silicone Caulk
- Black spray paint

Cutouts for Inlet Tube and Plug

1. Remove the lid and gasket from the assembly and set aside. They are not altered during the construction.
2. The short edges are sides A and B. The long edges are sides C and D. The bottom side is side E
3. Side A will be for the plug. The center of the plug hole will be ⅞" from the edge of side E and 1.5" from sides C and D.
4. Using power drill or drill press, cut a hole in the enclosure just large enough to fit the plug.
5. Test to make sure the plug fits snugly in the drilled hole. Re-drill hole with slightly bigger bit until plug fits snugly.
6. The square cutouts for the tubes will be on sides C and D, next to side B. The squares are 1-1/16" on each side. The cutout should be 0.5" from the edge of side B and ⅜" from the bottom side E. The cutout should be a little higher than midline to account for space needed during instrument installation.
7. Using a Dremel or other small saw, cut along the lines on both sides, measured in the previous step. Make sure to limit overshooting the lines to avoid needing to use more silicone caulk when sealing the enclosure.
8. File down any rough corners and edges to create as smooth an edge as possible.
9. Test fit by sliding tube through both square holes. Repeat steps 7 and 8 until tube can slide tightly through both cutouts.
10. Using compressed air, clean out any metal shavings from cutouts and enclosure.
11. The final enclosure should look similar to the following pictures.



Pictures for Cutouts Step 11.

Plug Wiring and Installation

1. Following the steps in the cable assembly section, solder the wires to be connected to the circuit to the male end of the plug in the same orientation as was followed in the cable assembly.
2. With the hole drilled so that plug fits snugly, insert the plug into the hole so that the female end is out of the enclosure and the soldered wires into the enclosure.
3. While holding the plug in place, apply a small amount of silicone all around the outside of the plug against the enclosure (although the plug makes its own seal, this is for added protection).
4. Install the hex nut that holds the plug in place. It will compress the silicone that was applied creating a watertight seal.

Inlet Tube Installation

1. Put a piece of tape (approx .75 in width) all the way around in the lengthwise center of the tube, this will be the LED and sensor area that is not to be painted.
2. Using the black spray paint, paint the entire surface of the acrylic tube so that no ambient light is able to enter the tube through the acrylic.
3. Tape around the inside of the newly cut square opening in the enclosure to avoid scratching the acrylic tube.
4. Put the acrylic tube through the holes cut into the enclosure centering it on the enclosure.
5. Tape to hold in place while applying the waterproofing.
6. Tape off areas on both the acrylic tube and outside of the enclosure to avoid getting the silicone in areas where it is undesired.
7. Apply silicone to both the inside and outside of the enclosure on all sides of the acrylic tube to completely protect from water intrusion

Cable Assembly

Parts Required

- Switchcraft Male Cable Mount Plug Assembly
- Tensility PVC Cable
- Silicone Caulk

Tools Required

- Wire stripper and cutter
- Soldering iron
- Multimeter or continuity tester

Steps

1. Strip a maximum of 0.625” (0.500” should be more than adequate) of outer insulation from one end of the PVC cable.
2. Strip a maximum of of 0.218” from each conductor within the cable.
3. Tin the exposed end of each conductor with the soldering iron.
4. Open the product datasheet and follow the instructions for proper assembly of plug components onto the cable. They can be found on page 2 of the document. If you cannot click the link, open the “Switchcraft Cable Mount Male Plug Drawing.pdf” file in the “Data Sheets folder”.
5. Make sure all plug assembly pieces are far enough away from the end so they do not interfere with soldering.
6. Next, following the below color scheme, solder each conductor into the specified connector. See page 1 of the datasheet for the 6-conductor orientation and number scheme.
    a. 1 - black (GND)
    b. 2 - red (+3.3V)
    c. 3 - green (BUSY)
    d. 4 - yellow (SCL)
    e. 5 - blue (SDA)
    f. 6 - white (UNUSED PIN)
7. Using a multimeter or continuity tester, test for continuity between the solder joint and front of the plug.

Circuitry

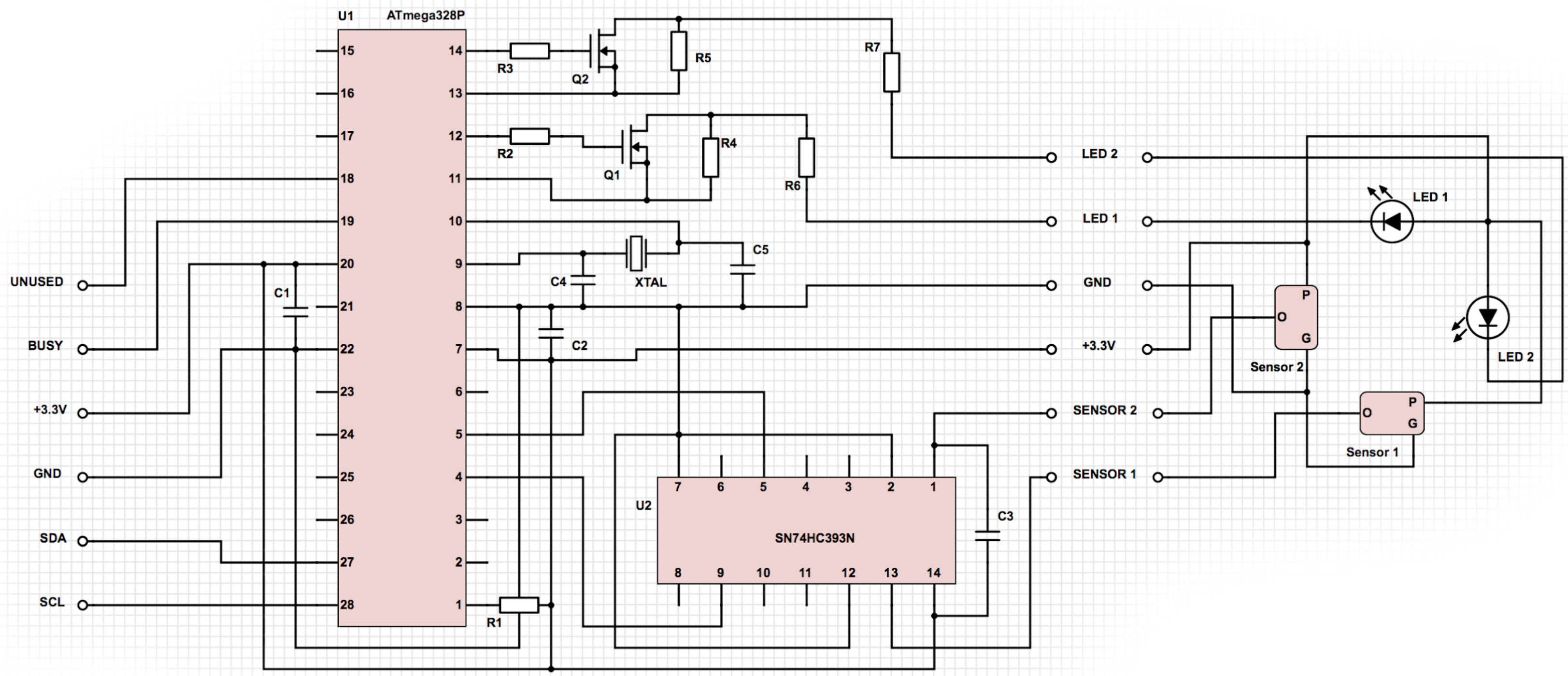
The turbidity sensor schematic is shown on the following page, with the abbreviated Bill of Materials below to serve as a key to identify the individual parts in the schematic. For our build, this circuit fit on a 15 by 20 hole perfboard with little extra room. Since it is assumed that a production version of the turbidity sensor would use a custom printed circuit board, the perfboard layout is not described in detail in this documentation.

As is mentioned in the accompanying Project Design Notes documents (Calibration section), the design as shown here produced some saturation/non-linear behavior from the light sensors, which limited the amount of data that could be fit for conversion to NTU. If the MOSFET and fixed resistor scheme was attempted again, we would recommend decreasing R6/R7, which would increase the higher LED brightness for side-scatter measurements, and increasing R4/R5 so that R4+R6 and R5+R7 (which determines the lower LED brightness for transmission measurements), is increased. These changes would increase the side-scatter frequencies and decrease the transmission frequencies in low turbidity situations, which should result in useful data collection over a larger range of turbidity.

Bill of Materials

Symbol	Part	Manufacturer	Digi-Key Part Number	Quantity
C1, C2, C3	0.1 uF Ceramic Capacitor	KEMET	399-4329-ND	3
C4, C5	18 pF Ceramic Capacitor	KEMET	399-9718-ND	2
Q1, Q2	2N7000 N-Channel MOSFET	ON Semiconductor	2N7000TACT-ND	2
R1	10 kOhm Resistor	Stackpole Electronics	RNF18FTD10K0CT-ND	1
R2, R3	470 Ohm Resistor	Stackpole Electronics	RNF14FTD470RCT-ND	2
R4, R5	976 Ohm Resistor	Yageo	976XBK-ND	2
R6, R7	174 Ohm Resistor	Yageo	174XBK-ND	2
L1, L2	860 nm Infrared LED	OSRAM Opto Semi	475-3043-1-ND	2
U1	ATmega328P Microcontroller	Microchip Technology	ATMEGA328P-PU-ND	1
U2	SN74HC393N Dual Binary Counter	Texas Instruments	296-8319-5-ND	1
U4, U3	Light Sensor	AMS	TSL238-TCT-ND	2
X1	8 MHz Crystal	TXC Corporation	887-1008-ND	1

Schematic


U1
ATmega328P
R3
Q2
R5
R7
R2
Q1
R4
R6
C4
XTAL
C5
C1
C2
U2
SN74HC393N
C3
UNUSED
BUSY
+3.3V
GND
SDA
SCL
R1
LED 2
LED 1
GND
+3.3V
SENSOR 2
SENSOR 1
LED 1
LED 2
Sensor 2
Sensor 1

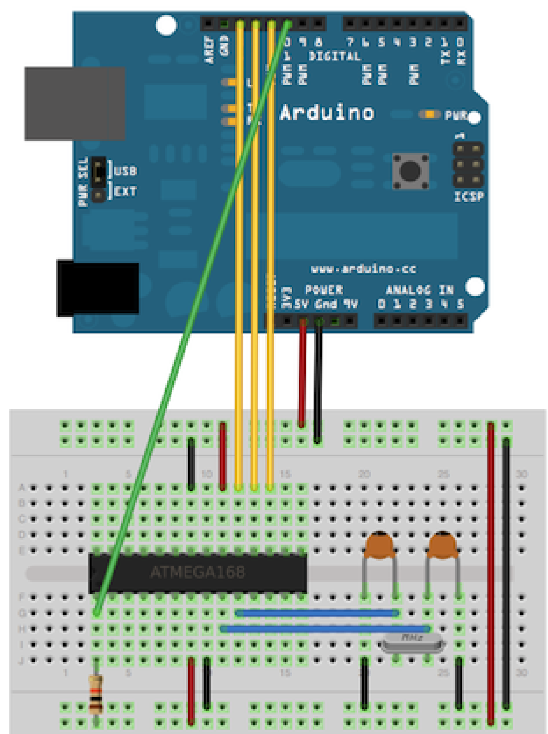
Programming Instructions

This section will explain how the ATmega328P is programmed to work in a standalone circuit, and how to program it externally without removing it from the sensor's circuit. Most of this process follows the "[From Arduino to a Microcontroller on a Breadboard]" tutorial with some changes for implementing the 8 MHz external crystal. The images in this section are taken from this tutorial.

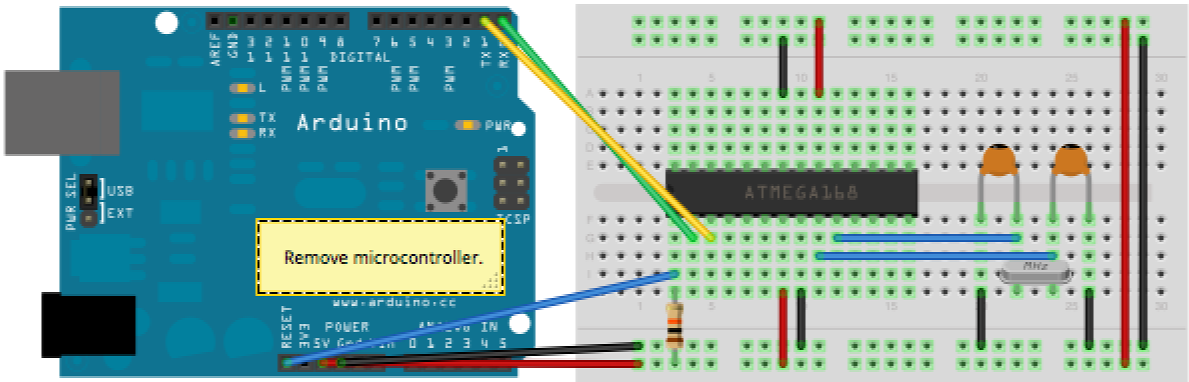
Programming a New ATmega328P Chip

The first step is to burn the Arduino bootloader on a new ATmega chip, which requires using an Arduino Uno board as an in-system program (ISP). The step-by-step process is below.

1. Upload the ArduinoISP sketch (one of the Built-in Example sketches in the Arduino IDE) to the Arduino Uno board.
2. Wire up the circuit shown in the diagram to the right, with a couple changes. Besides the Arduino Uno and the ATmega328P, the other required parts are an 8 MHz crystal, 10 kOhm resistor, and two 18 pF ceramic capacitors. Also, instead of powering the breadboard with 5V, you should use 3.3V.
3. Select "Arduino Pro or Pro Mini" from the Tools > Board menu and "ATmega328P (3.3V, 8MHz)" from the Tools > Processor menu.
4. Select "Arduino as ISP" from Tools > Programmer
5. Run Tools > Burn Bootloader



The ATmega is now ready to be programmed with the sensor code. This can be done using the Arduino Uno board with its microcontroller removed. From this point on, the only connections needed are the ones shown in the diagram below. Again, 3.3V should be used for power instead of 5V. The Board and Processor selections made above should stay the same. From there, any sketch can be uploaded to the ATmega using the usual process.



<u>Programming the ATmega328P in the Sensor</u>

On our sensor’s circuit board, there are five sockets which allow the connections in the diagram above to be made to RESET, 3.3V, GND, TX, and RX on an Arduino Uno board so the chip can be reprogrammed without removing it from the sensor. Note that the diagram uses 5V power, but our circuit needs 3.3V instead. Simply make these connections to an Uno (with the microcontroller removed), and upload to the ATmega using the usual process.