

This is the Revision A version of the [Compass360 RoboBrick](#). The status of this project is that it has been [replaced](#) by the [revision B](#) version.

# Compass360 Robobrick (Revision A)

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## 1. Introduction

The Compass360 RoboBrick uses a 1625 analog compass module from [Dinsmore Instrument Company](#) to detect magnetic bearing with a resolution approximately 10 bits. You should be informed that the magnetic environment inside dwellings can induce substantial errors in magnetic bearing of more than 10 degrees. (You have been warned!)

## 2. Programming

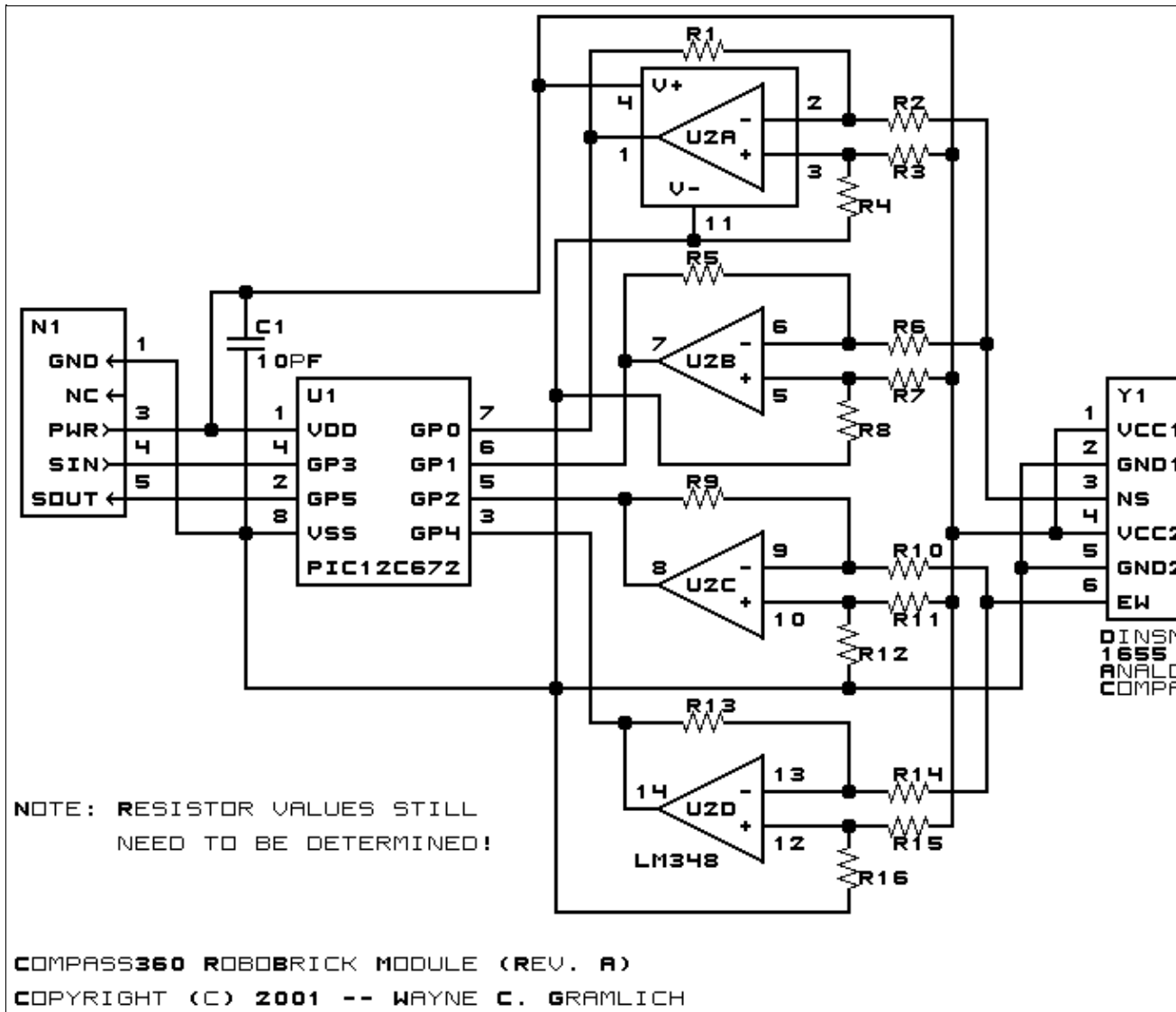
There is no programming specification yet.

## 3. Hardware

The hardware consists of a circuit schematic and a printed circuit board.

### 3.1 Circuit Schematic

The schematic for the Compass360 RoboBrick is shown below:



The parts list kept in a separate file --- [compass360.ptl](#).

## 3.2 Printed Circuit Board

The printed circuit board files are listed below:

[compass360\\_back.png](#)

The solder side layer.

[compass360\\_front.png](#)

The component side layer.

[compass360\\_artwork.png](#)

The artwork layer.

[compass360.gbl](#)

The RS-274X "Gerber" back (solder side) layer.

[compass360.gtl](#)

The RS-274X "Gerber" top (component side) layer.

[compass360.gal](#)

The RS-274X "Gerber" artwork layer.

[compass360.drl](#)

The "Excellon" NC drill file.

[compass360.tol](#)

The "Excellon" tool rack file.

## 4. Software

There is no software yet.

## 5. Issues

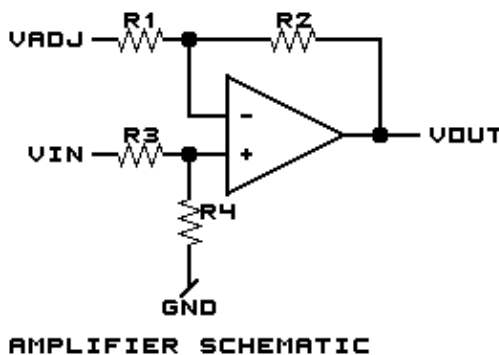
The following issues have come up:

- The input signals should go to plus inputs, not the minus inputs. (I.e. they are swapped.)
- There needs to be a 1 volt adjustment voltage fed into the minus input, not Vcc.
- The revision A brick is mislabeled as ANALOGIN4-A and should be labeled COMPASS360-A.
- Make the holes for N1 (size 3) smaller (size 2).

## A. Appendix – Designing the Amplifiers

### A1. Basic Amplifier Equations

In order to understand how the resistors around the operational amplifiers are picked it is necessary to analyze one of the amplifier circuits. We'll do the analysis the amplifier below:



Let's call  $V_{in}$  the input voltage to  $R_3$  and  $V_{adj}$  the adjustment voltage input to  $R_1$ .

$V_+$  is the voltage input to the positive side of the operational amplifier and  $V_-$  is the input to the negative side. The trick with operational amplifiers is that they have very high input impedances; hence, the current into and out of both the  $V_+$  and  $V_-$  terminals is assumed to be zero. In addition, since we have a properly designed feedback circuit, the operational amplifier will work like crazy to keep  $V_+$  and  $V_-$  equal to one another; thus, we just assume that  $V_+$  is always equal to  $V_-$ . These assumptions are summarized as:

$$(1) V_+ = V_-$$

$$(2) I_{V_+} = 0$$

$$(3) I_{V_-} = 0$$

R3 and R4 form a simple voltage divider of  $V_{in}$ :

$$(4) V_+ = V_{in}R_4/(R_3 + R_4)$$

The voltage drop across  $R_1$  is:

$$(5) V_{R_1} = V_{adj} - V_- \\ = V_{adj} - V_+ \\ = V_{adj} - V_{in}R_4/(R_3 + R_4)$$

Using Ohm's law, we can compute the current through  $R_1$  as:

$$(6) I_{R_1} = V_{R_1} / R_1 \\ = [V_{adj} - V_{in}R_4/(R_3 + R_4)] / R_1 \\ = V_{adj}/R_1 - V_{in}R_4/[R_1(R_3+R_4)]$$

Since there is no current into  $V_-$ , the current through  $R_2$  is the same as the current through  $R_1$ :

$$(7) I_{R_2} = I_{R_1}$$

The voltage drop across  $R_2$  is computed using Ohm's law as:

$$(8) V_{R_2} = I_{R_2}R_2 \\ = I_{R_1}R_2 = \\ = [V_{adj}/R_1 - V_{in}R_4/[R_1(R_3+R_4)]]R_2 \\ = V_{adj}R_2/R_1 - V_{in}R_2R_4/[R_1(R_3+R_4)]$$

The voltage out ( $V_{out}$ ) is:

$$(9) V_{out} = V_- - V_{R_2} \\ = V_+ - V_{R_2} \\ = V_{in}R_4/(R_3 + R_4) - [V_{adj}R_2/R_1 - V_{in}R_2R_4/[R_1(R_3+R_4)]] \\ = V_{in}R_4/(R_3 + R_4) - V_{adj}R_2/R_1 + V_{in}R_2R_4/[R_1(R_3+R_4)] \\ = V_{in}R_4/(R_3 + R_4) + V_{in}R_2R_4/[R_1(R_3+R_4)] - V_{adj}R_2/R_1 \\ = V_{in}[R_4/(R_3 + R_4) + R_2R_4/[R_1(R_3+R_4)]] - V_{adj}R_2/R_1 \\ = V_{in}[R_4/(R_3 + R_4) + (R_2/R_1) \times R_4/(R_3+R_4)] - V_{adj}R_2/R_1 \\ = V_{in}[R_4/(R_3 + R_4) \times (1 + R_2/R_1)] - V_{adj}R_2/R_1 \\ = V_{in}[(1 + R_2/R_1) \times R_4/(R_3 + R_4)] - V_{adj}R_2/R_1$$

The equation can be rewritten as:

$$(10) V_{out} = V_{in} \times G - V_{off}$$

where the amplifier gain is G:

$$(11) G = (1 + R_2/R_1) \times R_4/(R_3 + R_4)$$

and the voltage offset is  $V_{off}$ :

$$(12) V_{off} = V_{adj}R_2/R_1$$

## A2 Initial Resistor Values

For the first iteration of resistor values, we want the amplifier to take the voltage output from the Dinsmore 1655 analog compass module of 1.9 to 3.1 volts and convert that to a voltage swing of 0 to 5 volts ( $V_{cc}$ ).

Let  $V_{low}$  lowest input voltage and  $V_{high}$  be the high input voltage. What we want is:

$$(13) \begin{aligned} V_{out} &= (V_{in} - V_{low})[V_{cc}/(V_{high}-V_{low})] \\ &= V_{in}[V_{cc}/(V_{high}-V_{low})] - V_{low}[V_{cc}/(V_{high}-V_{low})] \end{aligned}$$

Matching to equation (13) to equation (10) in the previous section, the gain (G) is:

$$(14) G = V_{cc}/(V_{high}-V_{low})$$

and the voltage offset ( $V_{off}$ ) is:

$$(15) V_{off} = V_{low}[V_{cc}/(V_{high}-V_{low})]$$

Starting with the voltage offset:

$$(16) \begin{aligned} V_{off} &= V_{low}[V_{cc}/(V_{high}-V_{low})] \\ &= 1.9 [ 5 / (3.1 - 1.9) ] \\ &= 1.9 ( 5 / 1.2 ) \\ &= 1.9 \times 4.17 \\ &= 7.92 \end{aligned}$$

Now combining equations (16) and (12) from the previous section, we get:

$$(17) V_{off} = V_{adj}R_2/R_1$$

At this point we have to pick a value for  $V_{adj}$ . Initially, I tried to set  $V_{adj}$  to  $V_{cc}$ , but when I worked through the equations,  $R_4$  had a negative value. Since I can not buy negative resistor values, I decided to drop  $V_{adj}$  down a little. At  $V_{adj}$  equal to 2.5 volts, it started to work. I ultimately decided to set  $V_{adj}$  to 1 volt because I liked how the numbers worked out a little better.

Now substituting in values for  $V_{off}$  and  $V_{adj}$  we get:

$$(18) 7.92 = 1 \times R_2/R_1$$

or

$$(19) R_2/R_1 = 7.92$$

I'll pick  $R_1$  to be 100K Ohms thereby getting:

$$(20) R_2/100K = 7.92$$

or

$$(21) R_2 = 792K$$

We'll round that down to 750K Ohms.

Now switching over to the gain side of the equation:

$$\begin{aligned}
 (22) \ G &= V_{cc}/(V_{high}-V_{low}) \\
 &= 5 / (3.1 - 1.9) \\
 &= 5 / 1.2 \\
 &= 4.17
 \end{aligned}$$

Now combining equation (22) with equation (11) from the previous section, we get:

$$(21) \ G = (1 + R_2/R_1) \times R_4/(R_3 + R_4)$$

and substituting for G, R<sub>1</sub> and R<sub>2</sub> we get:

$$\begin{aligned}
 (22) \ 4.17 &= (1 + 750K/100K) \times R_4/(R_3 + R_4) \\
 &= (1 + 7.5) \times R_4/(R_3 + R_4) \\
 &= 8.5 \times R_4/(R_3 + R_4) \\
 (23) \ .49 &= R_4/(R_3 + R_4)
 \end{aligned}$$

Rounding .49 to .5, and picking R<sub>4</sub> to be 100K, we can trivially solve for R<sub>3</sub> to also be 100K.

$$(24) \ R_3 = 100K$$

Thus the final values are:

$$\begin{aligned}
 R_1 &= 100K \text{ Ohms} \\
 R_2 &= 750K \text{ Ohms} \\
 R_3 &= 100K \text{ Ohms} \\
 R_4 &= 100K \text{ Ohms} \\
 V_{adj} &= 1 \text{ Volt}
 \end{aligned}$$

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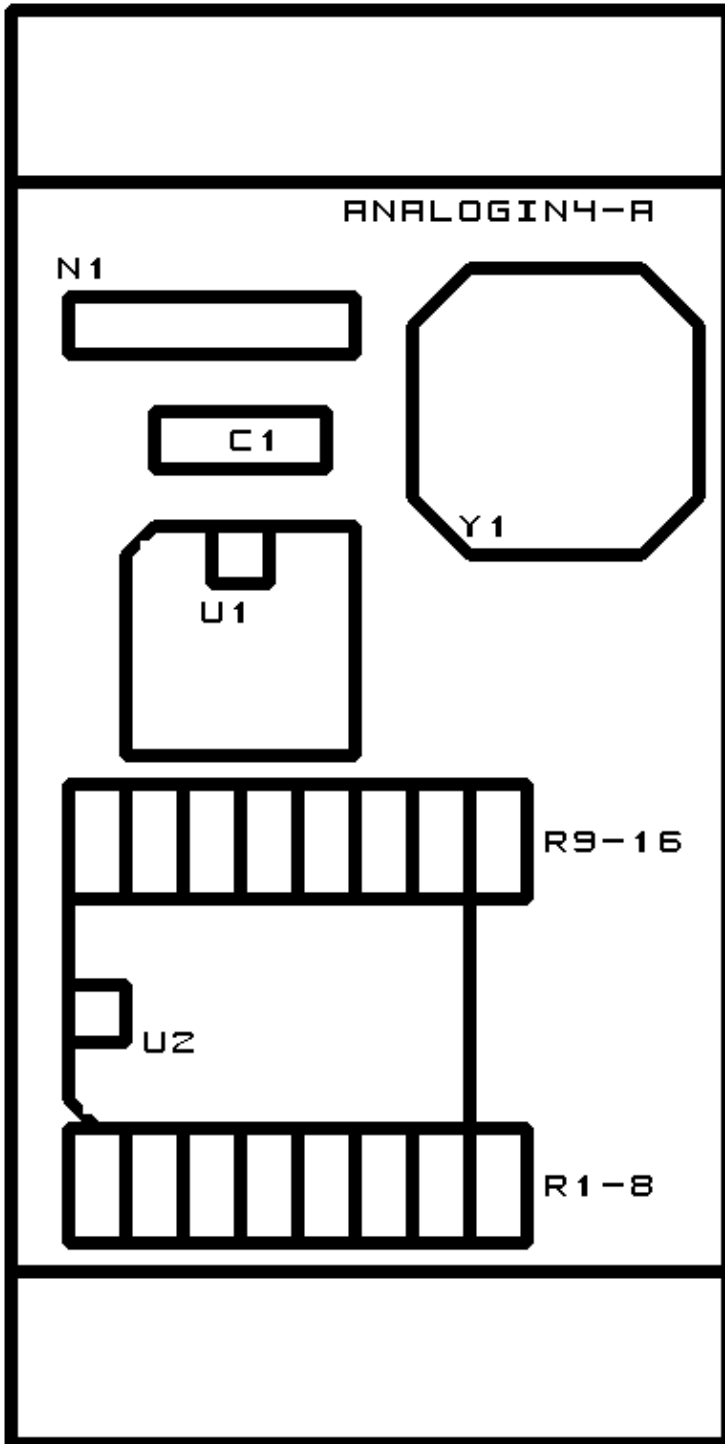


## A. Appendix A: Parts List

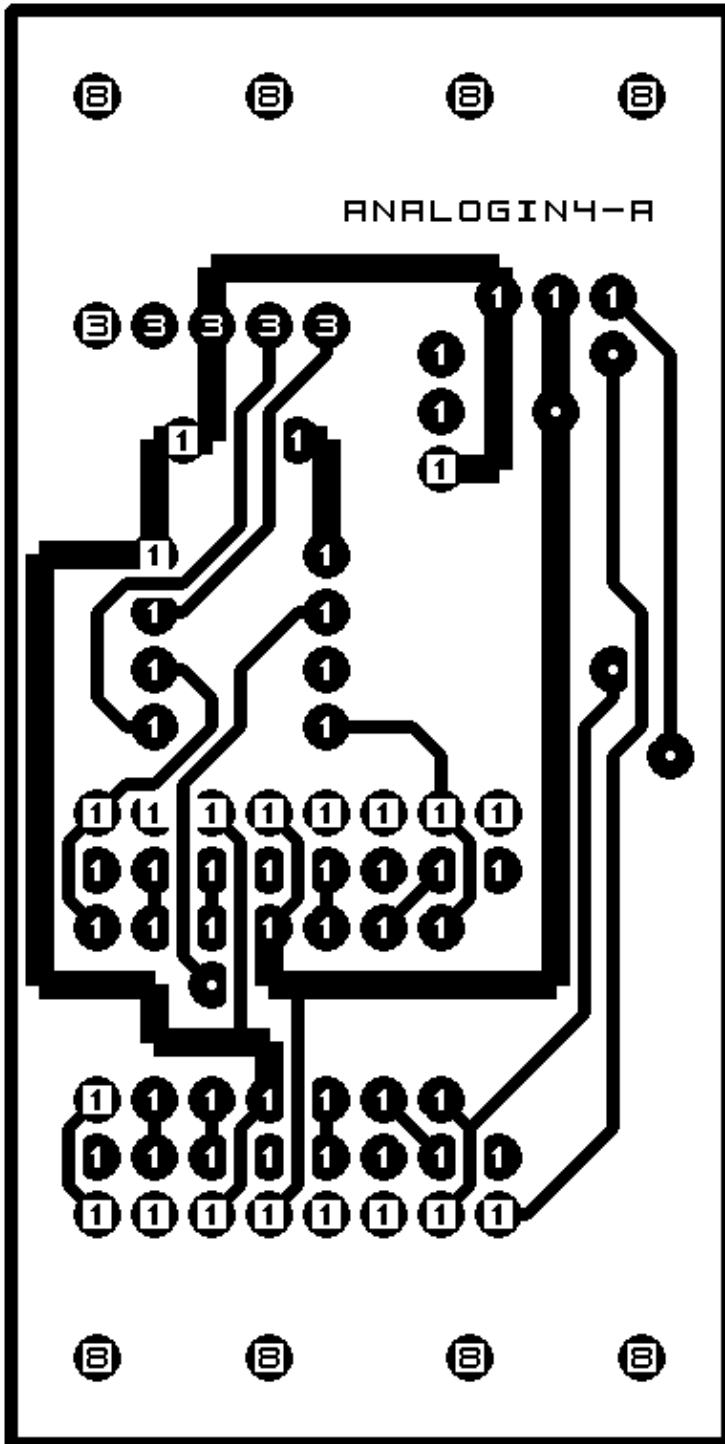
```
# Parts list for Compass360 RoboBrick (Rev. A)
#
C1: Capacitor10pF - 10 pF Ceramic Capacitor [Jameco: 15333]
R1: Resistor100K.Vertical - 100K Ohm 1/4 Watt Resistor [Jameco: 29997]
R2: Resistor750K.Vertical - 750K Ohm 1/4 Watt Resistor [Digikey: 750K-QBK-ND]
R3: Resistor56K.Vertical - 56K Ohm 1/4 Watt Resistor [Digikey: 56K-QBK-ND]
R4-5: Resistor100K.Vertical - 100K Ohm 1/4 Watt Resistor [Jameco: 29997]
R6: Resistor750K.Vertical - 750K Ohm 1/4 Watt Resistor [Digikey: 750K-QBK-ND]
R7: Resistor56K.Vertical - 56K Ohm 1/4 Watt Resistor [Digikey: 56K-QBK-ND]
R8-9: Resistor100K.Vertical - 100K Ohm 1/4 Watt Resistor [Jameco: 29997]
R10: Resistor750K.Vertical - 750K Ohm 1/4 Watt Resistor [Digikey: 750K-QBK-ND]
R11: Resistor56K.Vertical - 56K Ohm 1/4 Watt Resistor [Digikey: 56K-QBK-ND]
R12-13: Resistor100K.Vertical - 100K Ohm 1/4 Watt Resistor [Jameco: 29997]
R14: Resistor750K.Vertical - 750K Ohm 1/4 Watt Resistor [Digikey: 750K-QBK-ND]
R15: Resistor56K.Vertical - 56K Ohm 1/4 Watt Resistor [Digikey: 56K-QBK-ND]
R16: Resistor100K.Vertical - 100K Ohm 1/4 Watt Resistor [Jameco: 29997]
N1: Header1x5.RBSlave - 1x5 Male Header [5/40 Jameco: 160881]
U1: PIC12C672.Compass360 - Microchip PIC12C672 [Digikey: PIC12C672-04/P-ND]
U2: LM348 - Quad. Op Amp [Jameco: 23915]
Y1: DIN1655 - Dinsmore 1655 Compass Module [Dinsmore: 1655]
```



## B. Appendix B: Artwork Layer



### C. Appendix C: Back (Solder Side) Layer



### D. Appendix D: Front (Component Side) Layer

