This is the Revision A verion of the Compass360 RoboBrick. The status of this project is that it has been replaced by the CompassDT1 RoboBrick.

Compass360 Robobrick (Revision B)

Table of Contents

This document is also available in PDF format.

1. Introduction

The Compass360 RoboBrick uses a 1625 analog compass module from Dinsmore Instrument Company to detect magnetic bearing with a resolution approximately 8 bits. You should be informed that the magnetic enviroment inside dwellings can induce substantial errors in magnetic bearing of more than 10 degrees. (You have been warned!)

2. Programming

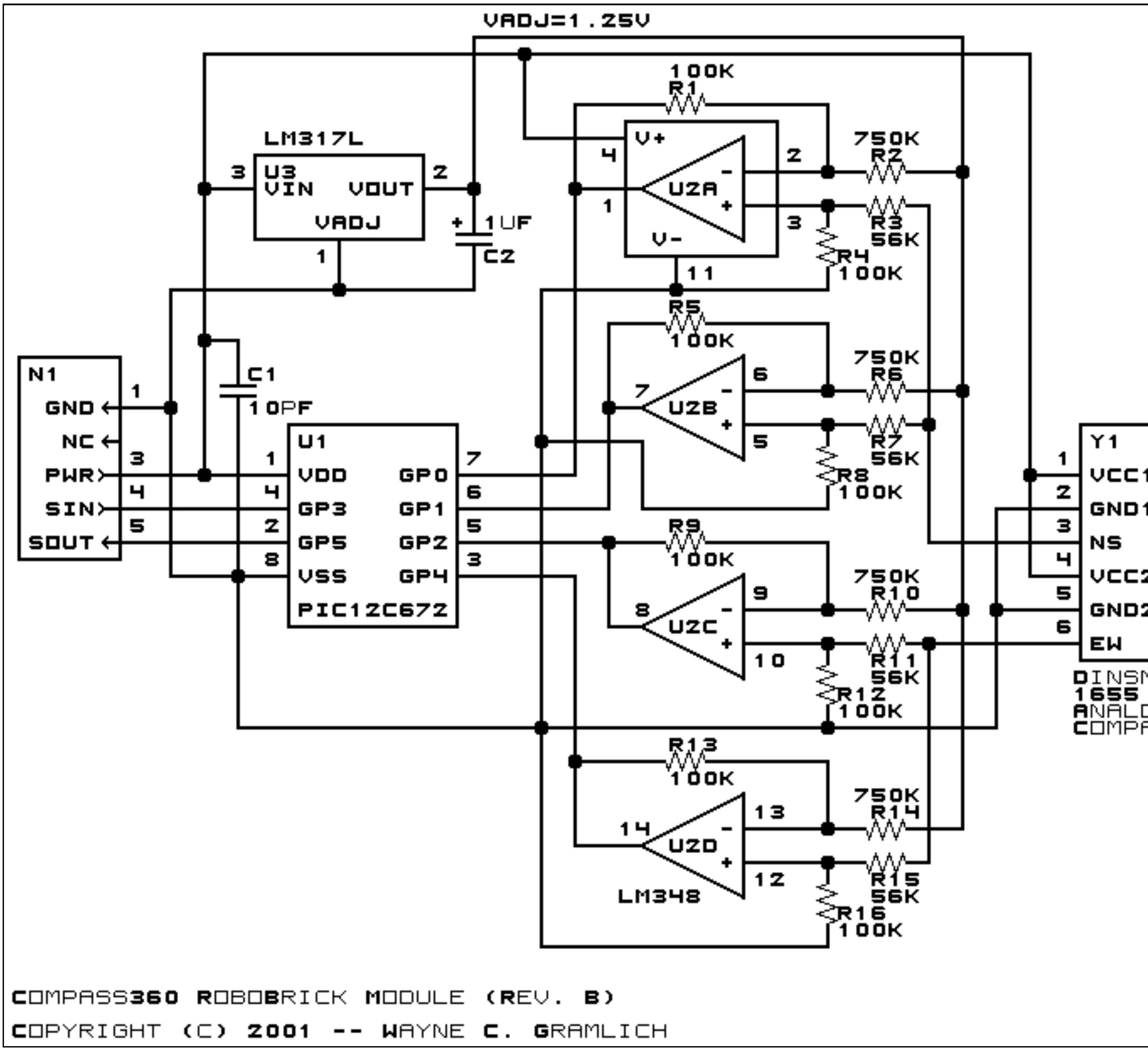
There is no programming specification yet.

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.

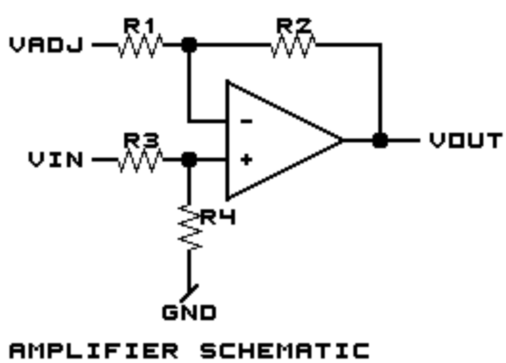
5. Issues

Any fabrication issues that come up are listed here.

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 cicuits. 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:

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

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

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

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

(7) $I_{R2} = I_{R_1}$

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

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

The voltage out (V_{out}) is:

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

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 hight input voltage. What we want is:

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

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:

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

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, R4 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, but R_3 had a very small value. The lower V_{adj} was dropped, the more reasonable the value of R_3 was. I ultimately decided to set V_{adj} to 1.25 volts because an LM317L will produce that voltage without needing any trim resistors.

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

$$(18)\ 7.92 = 1.25 \times R_2/R_1$$

or

$$(19)\ R_2/R_1 = 7.92\ /\ 1.25 = 5.83$$

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

$$(20)\ R_2/100K = 5.83$$

or

(21) $R_2 = 583K$

We'll round that down to 560K 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_1 and R_2 we get:

$$
\begin{aligned}
(22)\ 4.17 &= (1 + 560K/100K) \times R_4/(R_3 + R_4) \\
&= (1 + 5.6) \times R_4/(R_3 + R_4) \\
&= 6.6 \times R_4/(R_3 + R_4) \\
(23)\ .63 &= R_4/(R_3 + R_4)
\end{aligned}
$$

Picking R_4 to be 100K, we can trivially solve for R_3:

$$
\begin{aligned}
&(24)\ .63 = 100K / (R_3 + 100K) \\
&(25)\ .63 \times (R_3 + 100K) = 100K \\
&(26)\ R_3 + 100K = 100K / .63 = 159K \\
&(27)\ R_3 = 159K - 100K = 59K
\end{aligned}
$$

R_3 is rounded down from 59K down to 56K.

Thus the final values are:

R_1 = *100K Ohms*
R_2 = *750K Ohms*
R_3 = *56K Ohms*
R_4 = *100K Ohms*
V_{adj} = *1.25 Volt*

A. Appendix A: Parts List

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# Parts list for Compass360 RoboBrick (Rev. B)
#
C1: Capacitor10pF − 10 pF Ceramic Capacitor [Jameco: 15333]
C2: Capacitor1uF − 1 uF Tantalum Capacitor [Jameco: 33662]
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]
U3: LM317LZ −  [Jameco: 23552]
Y1: DIN1655 − Dinsmore 1655 Compass Module [Dinsmore: 1655]
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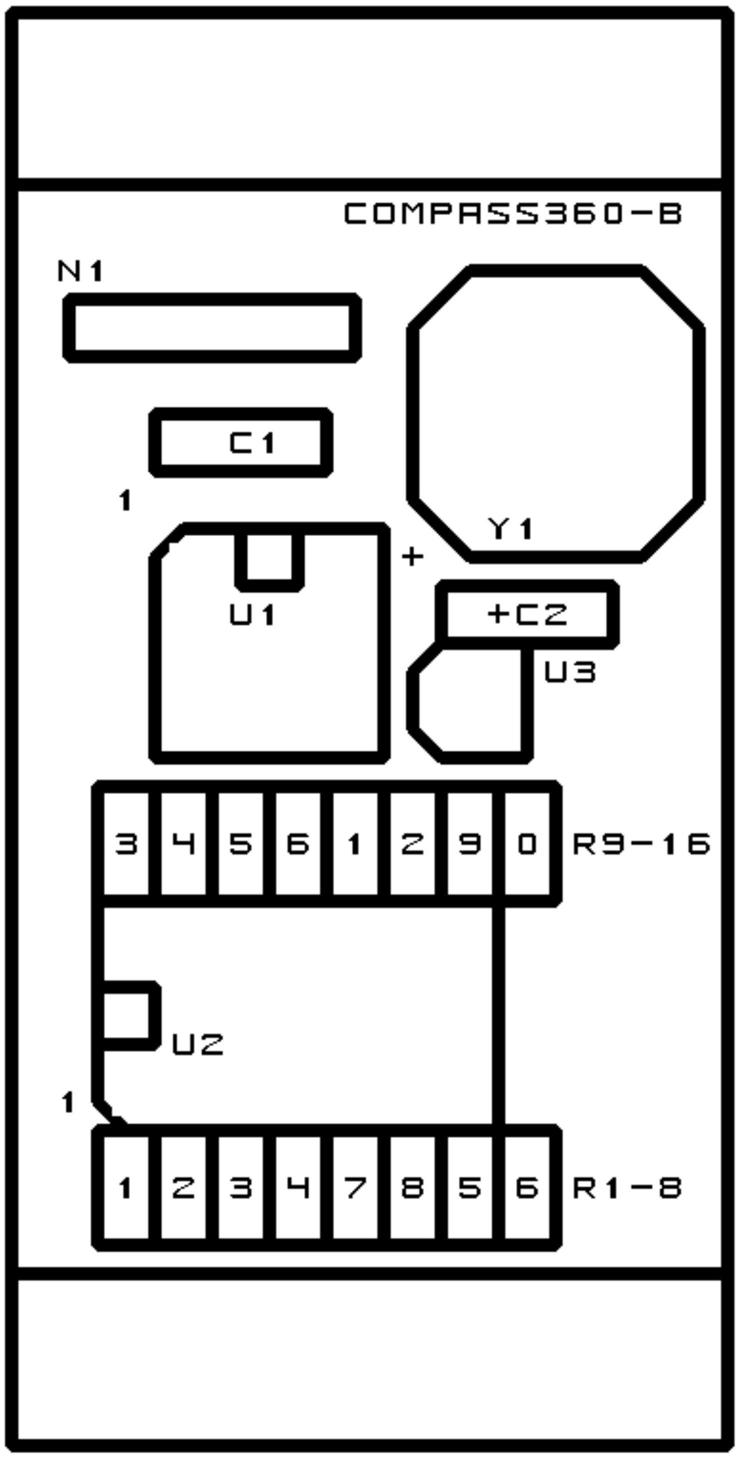
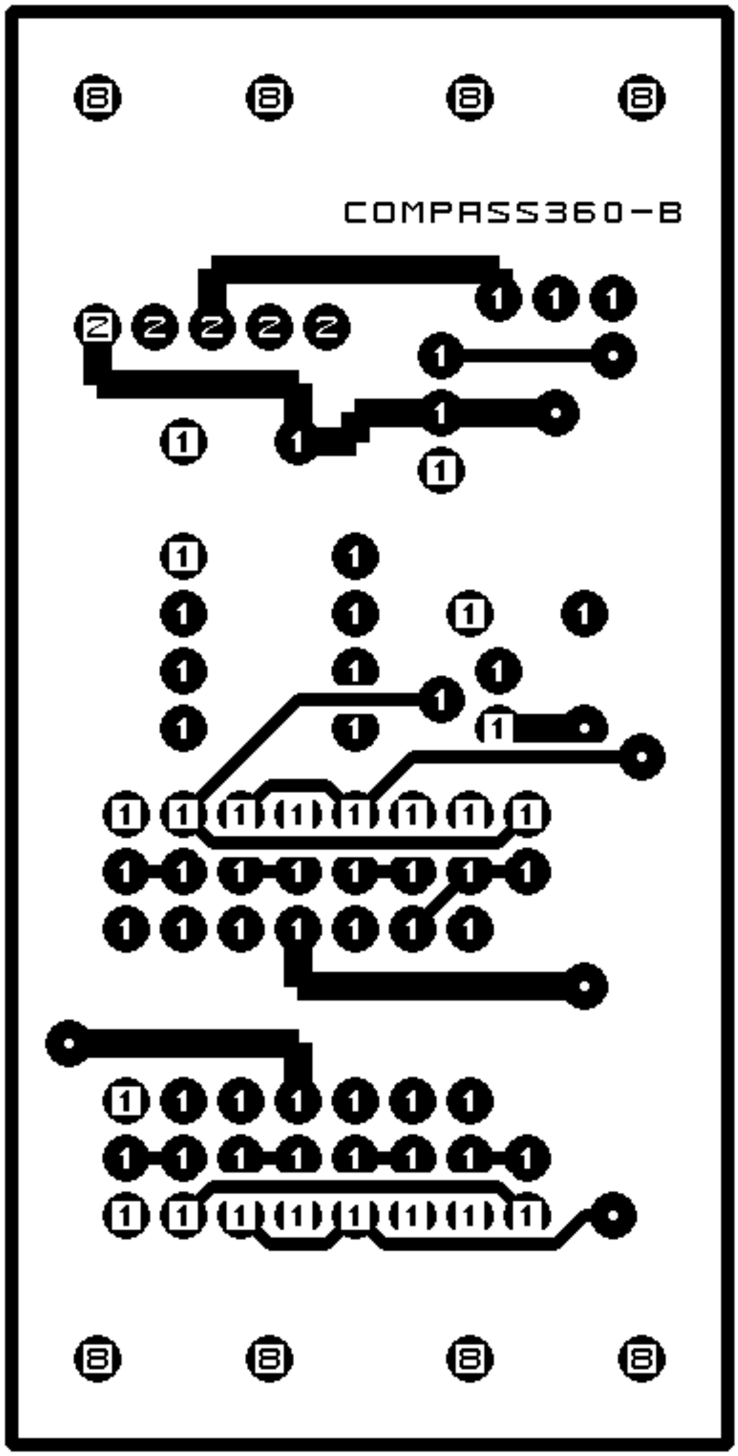
B. Appendix B: Artwork Layer



C. Appendix C: Back (Solder Side) Layer



D. Appendix D: Front (Component Side) Layer