Magnetometer Board

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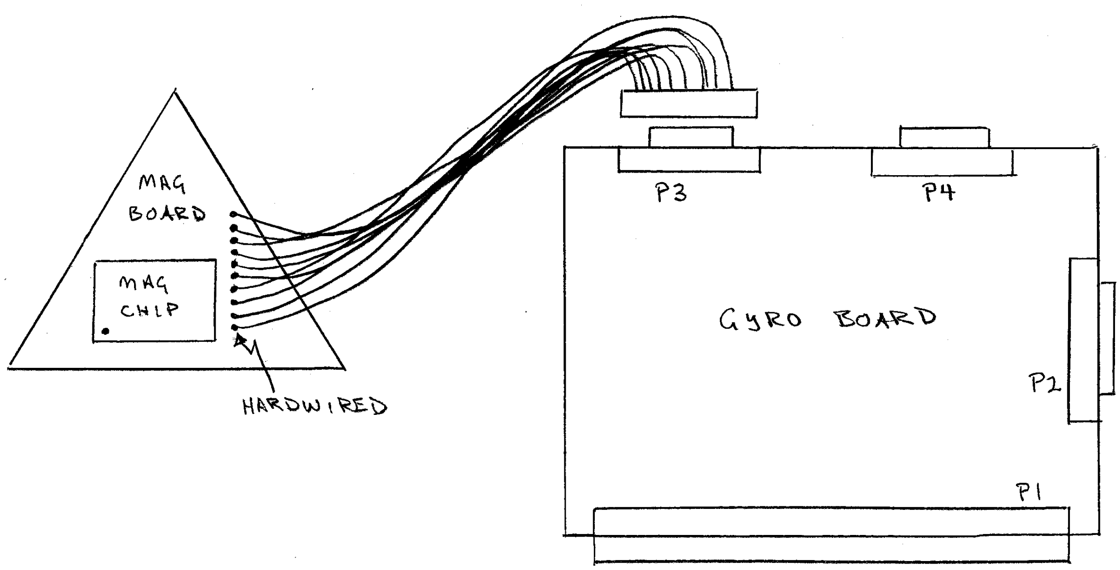
6-7-02

NOTE: Connector names in this document and other board documents refer assignments made for each CEE board schematic by the board designer. Several boards may have the same connector name (e.g., "P2"), so all connector references will also include board name.

Description

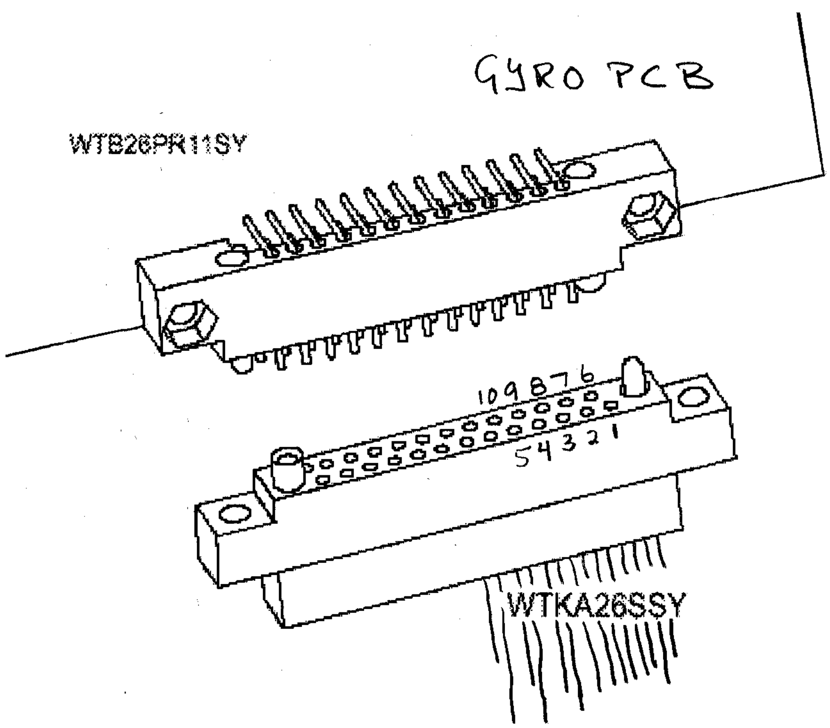
The Magnetometer Board is a triangular board mounted directly on the satellite exterior via a triangular bracket. Its function is to produce signals proportional to magnitudes of magnetic field components along 3 orthogonal directions, accomplished with the Honeywell HMC2003 3-axis magnetometer IC mounted on the Mag Board. The spec sheet on the HMC2003 is attached. The Mag Board also contains circuitry for generating high current pulses to "set" and "reset" the magnetometer (described below) and a 1-wire temperature sensor to detect the temperature of the mag chip. The Mag Board interfaces with the satellite system through the CEE-housed Gyro board. The Gyro board contains circuitry to condition the magnetometer signals prior to transmission to the I/O board. The Mag board is connected to the Gyro board via 10 lines. This is implemented via a 10-pin connector (Airborn WTKA10SSY) that plugs into Gyro board top receptacle "P3" (Airborn WTB10PR11SY); the connector has been pre-wired with free-hanging leads which must be soldered into the appropriate holes on the Mag board (hard-wired). The interface is shown below. This diagram shows position of pin 1 of the mag chip (dot) needed for association of B-field directions with chip orientation.



The line names are silkscreened on the Mag Board next to the solder holes. Below is shown the association of lines with pin numbers on Gyro receptacle P3.

Line	P3 pin	Function
Reset	1	Control sig to Reset Mag chip
1-Wire	2	1-Wire data line for Mag chip temperature sensor
+12V	3	Power for Mag chip
Vref	4	Ref voltage generated by Mag chip (~2.5V)
Ymag	5	B_y signal from Mag chip
Set	6	Control sig to Set Mag chip
+28V	7	Power for Set and Reset of Mag chip (Bus voltage)
GND	8	Ground
Zmag	9	B_z signal from Mag chip
Xmag	10	B_x signal from Mag chip

Below is shown the pin numbering of the mating connectors (26-pin version is shown - all that was available from Airborn documentation). The wires have been labeled (Hieu Le, Summer '01), but should be double-checked before soldering into the Mag board.



Signal conditioning

The Honeywell HMC2003 3-axis magnetometer produces signals Xmag, Ymag, Zmag, proportional to fields in x,y,z directions (see spec sheet for orientation). These signals are with respect to a fixed reference voltage, Vref ≈ 2.5V, generated by the magnetometer chip. The responsivity is $\rho \approx 1$V/gauss, so for B-field x-component B_x, the signal Xmag is Xmag =Vref+ρB_x; likewise for y and z. On the Gyro board the 3 mag signals are differentially amplified and inverted with respect to Vref, (gain G=-3.32), generating outputs [sent from gyro to I/O board], Xmag_out, Ymag_out, Zmag_out, where

$$\mathbf{Xmag\_out = Vref + G\ (Xmag - Vref) = Vref + G\rho Bx}$$

and likewise for y and z. In addition a single-pole low-pass filter is implemented on output signals with (measured) time constant $\tau \approx 40$ msec (3-dB frequency of 4 Hz) for anti-aliasing purposes.

Set/Reset of Magnetometer

The sign of the magnetometer responsivity can be changed by forcing a 3-4 Amp current pulse of appropriate direction through the SR+ to SR- pins of the chip. This also re-establishes calibration of the magnetometer, which might be upset by exposure to high external B-fields (generated by firing PPT's, for example). The resistance between SR^+ and SR- is ~ 4.5 Ω. On the mag board, pin SR^- is connected to ground. A brief (~ 1 μsec) exposure of pin SR^+ to a voltage of ~ +18V ("set") or ~ -18V ("reset") will reestablish calibration and establish the sign of the signal output in response to a B-field component being measured. The circuitry for generating these current pulses is onboard the mag board. This requires input of the satellite bus voltage (nominally 28V for UW, ~20V for VT), along with low-level "set" or "reset" signals generated by the gyro board. The gyro board generates the appropriate set and reset signals that the mag board needs in response to logic signals applied to pins 63 (set) or 64 (reset) on the backplane connector. Normally these pins should be LO. A positive (V> 2 V) pulse of ~ 10 μsec on pin 63 will set the magnetometer. A similar pulse on pin 64 will reset the magnetometer. Normally these pulses would not be applied more often than ~ 1 Hz, but ***can*** be applied at a rate up to ~ 10 Hz, with normal functioning of set or reset. A "reset" pulse can be applied a few μsec after termination of a set pulse or vice versa, but "set" and "reset" pulses must not overlap (this could destroy Q1 or Q2 on the mag board). [It is the set/reset ***sequence*** that is limited to 10 Hz.]

Using set and reset during an acquisition of a B-field component also affords a way to eliminate offsets from the signals. Let Xmag_out_set be the measured (at I/O board) signal recorded following a set pulse, and Xmag_out_reset be the signal recorded following a reset pulse. Offsets are eliminated (and a more accurate measurement of B_x afforded), by taking the difference divided by 2:

Xmag_accurate = (Xmag_out_set - Xmag_out_reset)/2

Bx_accurate=Xmag_accurate/ρG

[Note: G is negative, and ρ has the sign of responsivity corresponding to a set pulse. Of course the order can be reversed: reset, then set. Even if you do not choose to use this approach, a set or reset (depending on which sign you prefer) should be applied periodically to recalibrate the magnetometer.

Temperature Sensor

A 1-Wire temperature sensor (Dallas Semi DS18B20) is used to determine the temperature of the magnetometer IC, so that temperature corrections may be applied to the signals (if the sensor is temperature-calibrated). The 5V power for the sensor is generated on the mag board. Note that as supplied, the sensor (TO-92 transistor package) is positioned near the correct placement on the IC, but has not been affixed to the magnetometer chip (using thermal-conducting cement). This ***MUST*** be done prior to flight, or else the sensor will not have thermal contact with the mag IC, and its leads will likely be bent during launch vibration.

Magnetometer Board Testing.

This is best done using the gyro board interface. For testing, connect Gyro board to mag board, and power the following pins on the Gyro backplane connector:

34	Bus positive (~20V for VT)	[and/or pins 74, 115]
35	Ground bus negative)	[and/or pins 75, 116]
38	+12V	[and/or pins 78, 119]
39	-5V	[and/or pins 79, 120]
40	+5V	[and/or pins 80, 121]

If you do not plug into a backplane, wires with sockets that fit on the backplane connector pins can be used (e.g. Hirose, available from Digikey, part # H2BXT-10112-x4, where "x" is wire color) or discrete-wire IDC sockets (AMP MTA series, available from Digikey). Also, it is convenient to utilize the Gyro-to-I/O board connector (free-hanging leads on I/O end), to access the conditioned mag output signals (Xmag_out, Ymag_out, Zmag_out, and Vref) from the gyro board. The Gyro_to_IO connection is via 10 lines, with board and line connectors identical to those used for the Gyro_to_Mag connection. The Gyro board connector for output to I/O board is "P4" (see above diagrams). Again, the WTKA connector has been pre-wired, with wires labeled with the line names. For reference (and double-check) the below table shows correspondence between P4 pins and lines (lines for mag testing in bold):

P4 pin	Line
1	**Xmag_out**
2	**Zmag_out**
3	**GND**
4	**Vref**
5	Ygyro_out
6	**Ymag_out**
7	N/C
8	N/C
9	Zgyro_out
10	Xgyro_out

Static tests:

- Verify +12V current (into gyro) is ~ 20 mA (nominal current for mag chip)
- Verify +Bus current is very small (< 1 mA) [only used to charge up "set" caps]
- Verify "set" voltage is either ~21V (if Vbus>21V) or Vbus (if Vbus<21V), by monitoring the voltage (with respect to ground) of the barred end of D1 or D2 on the mag board
- Verify that Vref ~ 2.5V [on output to I/O board]
- Verify that Xmag_out, Ymag_out, Zmag_out are in the range ~ 0.5V to ~ 4.5V. These voltages will depend on orientation of the mag board with respect to terrestrial B-field (~.5 gauss). If the local B-field direction and magnitude are known, the responsivity (ρG, and sign of response after set or reset) can be calibrated at this point.

Set/reset tests:

Generate pulses of ~ 10 μsec duration at a repetition rate no higher than ~ 10 Hz, at HI voltage ≥ 2V (5 V is OK), LO voltage < 0.8 V. [Note: specs of backplane 3.3V logic are that $V_{LO,max}$=0.8V, $V_{HI,min}$=2.0V.]

Apply this signal to gyro backplane pin 63 (set), and verify that corresponding voltage spikes of ≥ 15 volts appear on the +SR pin of the magnetometer chip.

Apply this signal to gyro backplane pin 64 (reset), and verify that corresponding voltage spikes of ≤ -15 volts appear on the +SR pin of the magnetometer chip.
These spikes are of very short duration, exponentially decaying at time constant ~ 1μsec.

Record Xmag_out_reset, Ymag_out_reset, and Zmag_out_reset measured following a reset pulse.

Now apply the input signal to pin 63 (set), and note the new signal voltages (Xmag_out_set, Ymag_out_set, and Zmag_out_set).
You should find, approximately: Xmag_out_set = 2 Vref- Xmag_out_reset, and likewise for y and z signals.

Remaining work required on Mag Board prior to flight

1) Affix the DS18B20 1-Wire temperature sensor (TO-92 package with relatively long leads) to the mag chip using thermally conducting cement. This sensor is currently positioned near the correct spot.

2) Apply Dow Corning DC6-1104 sealant between base of VR1A (TO-92 transistor package next to mag chip) and the board, to prevent this part from bending under launch vibrations.

3) Determine correct wire lengths for Gyro-to-Mag connector, and cut leads. Solder leads into solder holes on the mag board (lead identification labeled, but cross-check using information above).

4) Use defluxer to clean any solder resin or other contaminant off of the board (both sides).

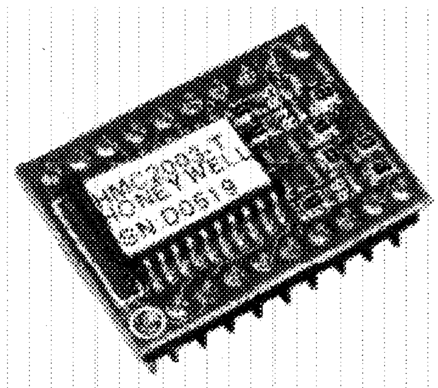
5) Spray both sides of the board with conformal coating.

Three-Axis Magnetic Sensor Hybrid

HMC2003

APPLICATIONS

- Compassing
- Navigation Systems
- Attitude Reference
- Traffic Detection
- Proximity Detection
- Medical Devices



A complete 3-axis magnetometer with analog output in a 20-pin hybrid DIP package. Uses Honeywell's sensitive HMC1001 and HMC1002 MR sensors and precision instrumentation amplifiers to measure x, y and z axes. Patented integral field straps are accessible for applying offset fields or closed loop operation.

FEATURES AND BENEFITS

Small Cost Effective Package	DIP-20 footprint (1 in. x .75 in.) allows easy insertion into system-level boards, reducing development costs.
Solid State	All components are solid state, improving reliability and ruggedness compared to mechanical fluxgates.
Wide Dynamic Range	Accurately measures fields from 40 micro-gauss to ±2 gauss at 1V/gauss. Low noise instrumentation amplifiers with 1kHz low pass filters, reject unwanted noise. There are no flux concentrators used in this design that can lead to hysteresis and non-repeatablilty.
Internal Reference	An externally accessible +2.5V reference improves measurement accuracy and stability. An on-board excitation current source reduces temperature errors and regulates the power supply input.
Offset and Set/Reset Straps	Magnetic field offsets or closed loop circuits can be applied using the built-in straps. Output signal accuracy may be enhanced by using the integral set/reset straps.
Non-Magnetic Material	All components are especially selected and packaged in nonmagnetic material to reduce magnetic distortion and offsets.

GENERAL DESCRIPTION

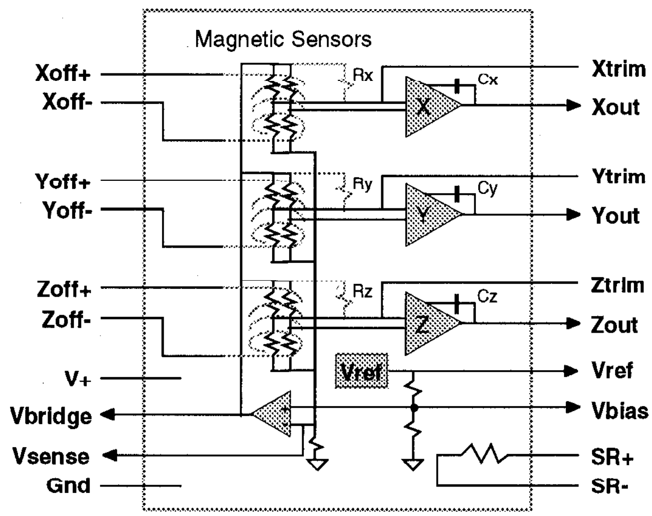
Honeywell's three-axis magnetic sensor hybrid uses three permalloy magnetoresistive transducers and custom interface electronics to measure the strength and direction of a magnetic field. These transducers are sensitive to magnetic fields along the length, width, and height (x, y, z axis) of the 20-pin dual-in-line hybrid. Fields can be detected less than 40 microgauss and up to ±2 gauss. Analog outputs are available for each x, y, z, axis from the hybrid. With the sensitivity and linearity of this hybrid, changes can be detected in the earth's magnetic field to provide compass headings or attitude sensing. The high bandwidth of this hybrid allows anomaly detection of vehicles, planes and other ferrous objects at high speeds.

The hybrid is packaged on a small board (1 in. x 0.75 in.) and has an on-chip voltage reference that operates from a single 6 to 15 V supply. The hybrid is ideal for applications that require two- or three-axis magnetic sensing and have a very tight size constraint and/or have their own electronics and only need a magnetic transducer front-end.

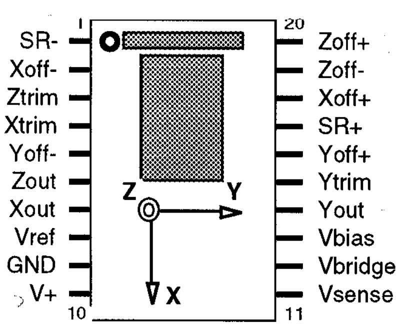
Integrated with the transducer bridge circuit is a magnetically coupled strap that replaces the need for external coils and provides various modes of operation. The Honeywell patented field offset straps (Xoff+ and Xoff-, etc.) can be used to electrically apply a magnetic field to the bridge to buck, or offset an applied field. This technique can be used to cancel unwanted ambient magnetic fields or in a closed loop field nulling measurement circuit. The offset straps nominally provide a 1 gauss field along the sensitive axis per 48 mA of offset current through it.

Magnetic transducers can be affected by high momentary magnetic fields that may lead to output signal degradation. In order to eliminate this effect, and maximize the signal output, a magnetic switching technique can be applied to the bridge using the SR+ and SR- pins that eliminates the effect of past magnetic history. Refer to AN-201 for applications information on Set/Reset operation.

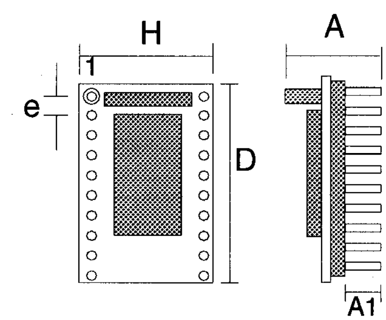
CIRCUIT DIAGRAM



PINOUT DIAGRAM



PACKAGE DRAWING



Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	11.43	12.45	0.45	0.49
A1	4.06	5.08	0.16	0.20
D	25.91	26.92	1.02	1.06
e	2.41	2.67	0.095	0.105
H	18.03	19.05	0.71	0.75

SPECIFICATIONS

Characteristic	Conditions (1)	Min	Typ	Max	Units (2)
Supply Voltage (3)		6		15	VDC
Supply Current				20	mA
Field Range		-2		2	gauss
Output Voltage		0.5		4.5	V
Resolution			40		µgauss
Bandwidth			1		KHz
Field Sensitivity		0.98	1	1.02	V/gauss
Null Field Output		2.3	2.5	2.7	V
Linearity Error	±1 gauss Applied Field Sweep		0.5	2	%FS
Linearity Error	±2 gauss Applied Field Sweep		1	2	%FS
Hysteresis Error	3 sweeps across ±2 gauss		0.05	.1	%FS
Repeatability Error	3 sweeps across ±2 gauss		0.05	.1	%FS
Offset Strap Resistance				10.5	Ω
Offset Strap Sensitivity		46.5	47.5	48.5	mA/gauss
Offset Strap Current				200	mA
Set/Reset Strap Resistance				6	Ω
Field Sensitivity Tempco			-600		ppm/° C
Null Field Tempco	Set/Reset not used		±400		ppm/° C
Null Field Tempco	Set/Reset used		±100		ppm/° C
Storage Temperature		-55		125	° C
Operating Temperature		-40		85	° C
Shock			100		g
Vibration			2.2		g rms
Power Supply Effect (shifts in Null Field Offset or Sensitivity)	Power Supply varied from 6 to 15VDC with ±1 gauss Applied Field sweep			0.1	%FS

(1). Unless otherwise stated, test conditions are as follows: power supply = +12VDC, ambient temp = 25°C, Set/Reset switching is active.
(2). Units: 1 gauss (G) = 1 Oersted (in air), 1G = 79.58 A/m, 1G = 10E-4 Tesla, 1G = 10E5 gamma.
(3). Transient protection circuitry should be added across V+ and Gnd if an unregulated power supply is used.

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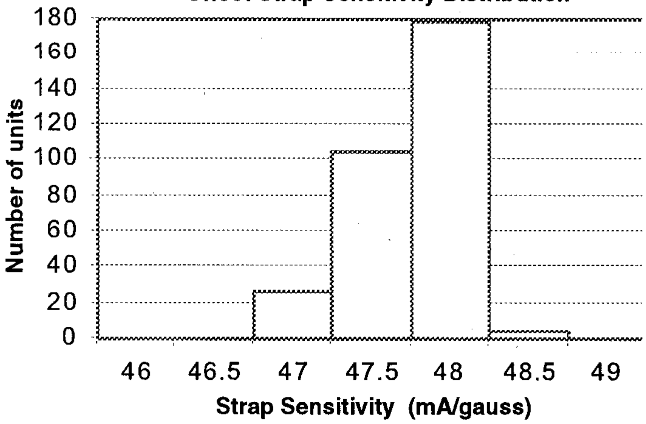
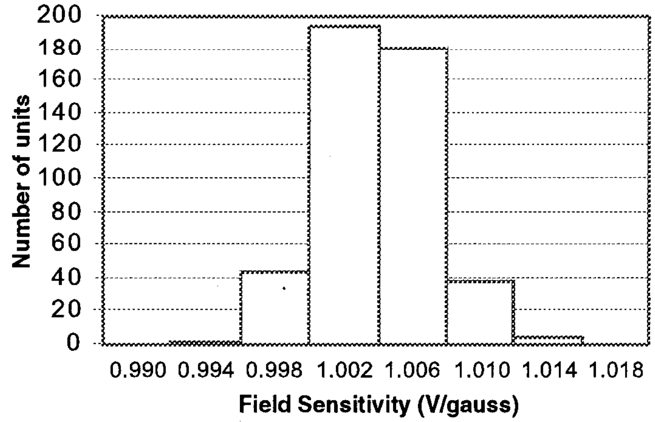
900151 Rev. C 10-97

KEY PERFORMANCE DATA

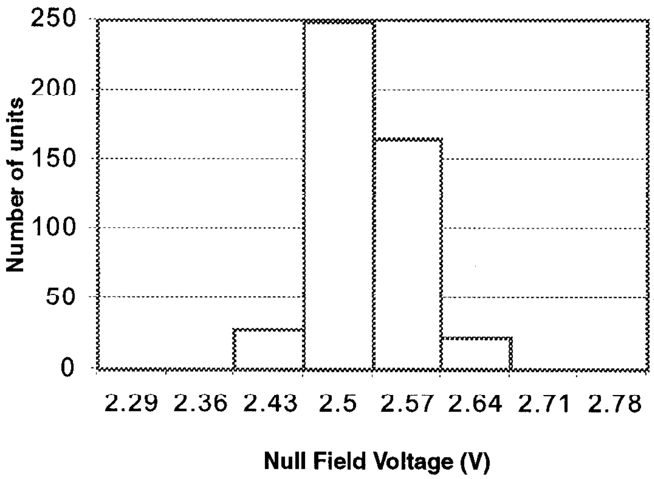
Offset Strap Sensitivity Distribution



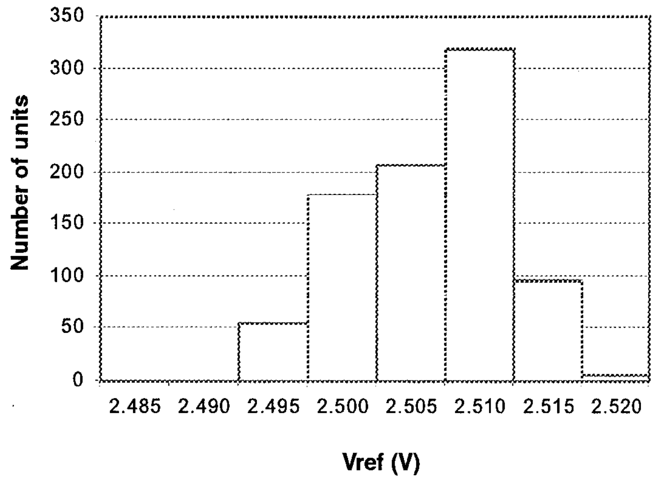
Field Sensitivity Distribution



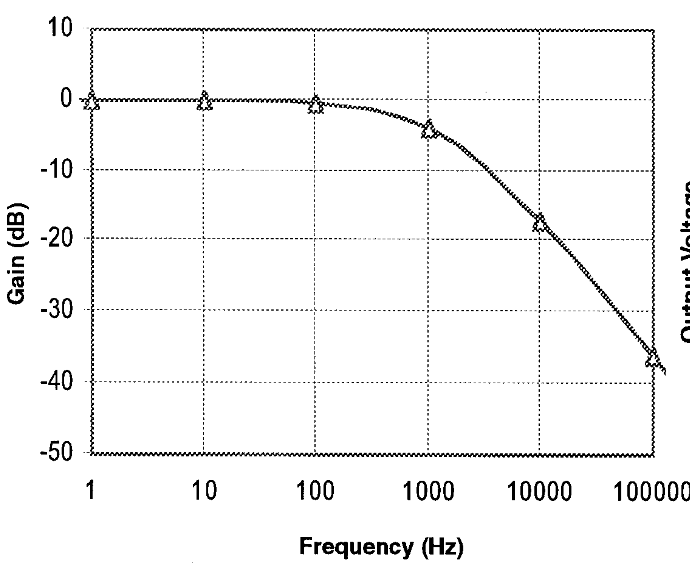
Null Field Distribution



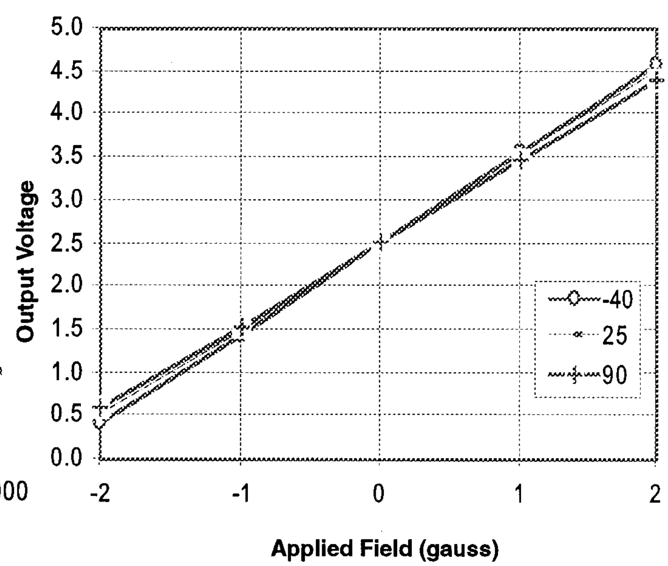
Vref Distribution

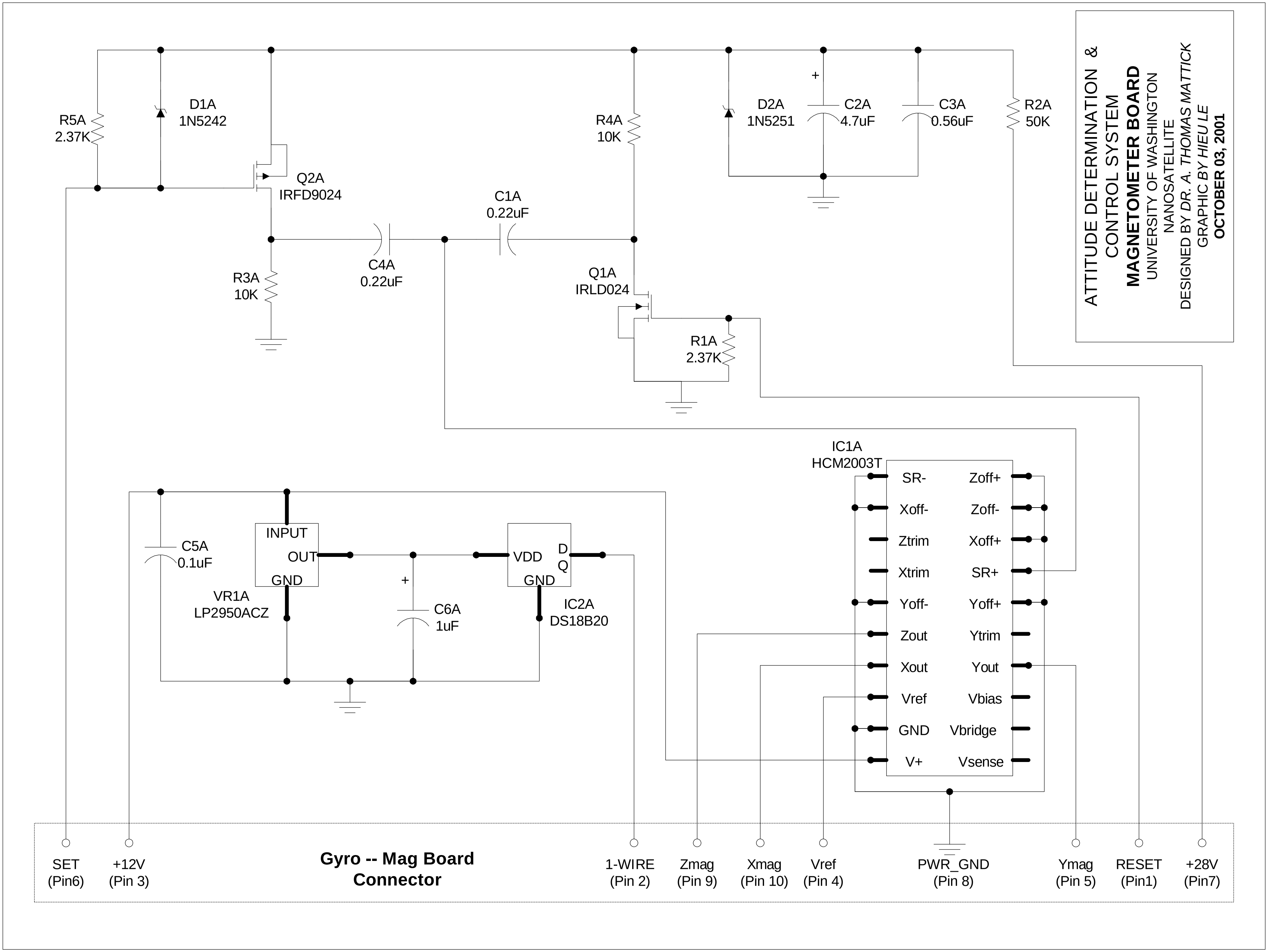


Bandwidth



Temperature Effects





R5A
2.37K
D1A
1N5242
Q2A
IRFD9024
R3A
10K
C4A
0.22uF
C1A
0.22uF
R4A
10K
Q1A
IRLD024
R1A
2.37K
D2A
1N5251
C2A
4.7uF
C3A
0.56uF
R2A
50K
ATTITUDE DETERMINATION &
CONTROL SYSTEM
MAGNETOMETER BOARD
UNIVERSITY OF WASHINGTON
NANOSATELLITE
DESIGNED BY DR. A. THOMAS MATTICK
GRAPHIC BY HIEU LE
OCTOBER 03, 2001
IC1A
HCM2003T
SR-
Xoff-
Ztrim
Xtrim
Yoff-
Zout
Xout
Vref
GND
V+
Zoff+
Zoff-
Xoff+
SR+
Yoff+
Ytrim
Yout
Vbias
Vbridge
Vsense
C5A
0.1uF
INPUT
OUT
GND
VR1A
LP2950ACZ
C6A
1uF
VDD
D
Q
GND
IC2A
DS18B20
SET
(Pin6)
+12V
(Pin 3)
Gyro -- Mag Board
Connector
1-WIRE
(Pin 2)
Zmag
(Pin 9)
Xmag
(Pin 10)
Vref
(Pin 4)
PWR_GND
(Pin 8)
Ymag
(Pin 5)
RESET
(Pin1)
+28V
(Pin7)

MAGNETOMETER BOARD COMPONENTS

		Mfg – part number	Package	Vendor	Packing Slip
Semiconductors					
D1	12-V Zener Diode	Diodes,Inc 1N5242B	DO-35	Digikey	DK01-8
D2	22-V Zener Diode	Microsemi 1N5251B	DO-35	Digikey	DK01-8
IC1	3-axis magnetometer	Honeywell HCM2003T			
IC2	1-wire temp sensor	Dallas Semi DS18B20	T0-92	Newark	NE01-4
Q1	N-Ch Power Mosfet	IRF IRLD024	4-pin DIP	Digikey	DK01-8
Q2	P-Ch Power Mosfet	IRF IRFD9024	4-pin DIP	Digikey	DK01-8
VR1	5.0 V Volt. Reg.	NSC LP2950ACZ-5.0	TO-92	Digikey	DK01-8
Resistors					
R1,R5	2.37K 1/8 W 1% MF	Xicon 270-2.37K	axial	Mouser	ME01-1
R2	49.9K 1/8 W 1% MF	Xicon 270-49.9K	axial	Mouser	ME01-1
R3,R4	10K 1/8 W 1% MF	Xicon 270-10K	axial	Mouser	ME01-1
Capacitors					
C1,C4	0.22uF, 50V metal Film	Panasonic ECQ-V1H224JL	radial	Digikey	DK01-8
C2	4.7uF, 35V tantalum	Kemet T350E475K035	radial	Mouser	ME01-5
C3	0.56uF, 50V metal film	Panasonic ECQ-V1H564JL	radial	Digikey	DK01-8
C5	0.1uF, 50V ceramic, X7R	BC Components K104K15X7RF5TL2	radial	Digikey	DK01-8
C6	1 uF, 25V tantalum	Kemet T350A105K025	radial	Mouser	ME01-5
Other					
Circuit Board, Polyimide		Prototron (Triangular)		Prototron	PR01-5