BILLINGSLEY MAGNETICS

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T F M 100G2

ULTRA MINIATURE
TRIAXIAL FLUXGATE MAGNETOMETER

April 26, 2005

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INDEX

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1. Introduction

The TFM100G2 is a miniature triaxial magnetometer for general magnetic measurements in laboratory or field applications, where critical magnetic measurements are required. This instrument is designed for highest reliability and uses no potentiometers or switches.

An instrument specification sheet is included in the Appendix.

2. Setup, Installation & Preparation for Use

Before use, a visual inspection of the unit must be performed. Any noticeable damages from shipment may lead to malfunction. The unit must be returned to the manufacturer if any defects are discovered.

The magnetometer's input/output must be wired into the user's system using the manufacturer supplied connector. The connector pin assignments are listed in Table 1.

1. Wire pin 1 to the positive terminal of the power supply.
2. Wire pin 4 to the negative terminal of the power supply.
3. Wire pins 6, 8 and 5 to the high inputs of the measuring device. These are the X, Y and Z outputs of the magnetometer, respectively.
4. Wire pin 3 to the low input of the measuring device. This pin is the signal ground reference.

Connector Pin Assignments	
Pin Number	Function
1	+ Power Input
2	N/C
3	Signal Ground
4	Power Ground
5	Z Output
6	X Output
7	Case Ground
8	Y Output
9	N/C

3. Operation

The magnetometer consists of three magnetic sensors, X, Y and Z, operating independently and simultaneously. Each sensor has an analog output corresponding to the component of the ambient magnetic field along its axis. The response of the sensor is proportional to the cosine of the angle between the applied field and the sensor's sensitive axis. The sensor's on-axis sensitivity is 100 μV/nT.

3.1 Bench Test

1. Adjust the power supply Voltage to input voltage between + 15 to + 34 VDC.
2. Adjust the current limit on the power supply to allow for an input current of 50 mA.
3. Connect the X, Y and Z outputs of the magnetometer to a measuring device that has an input impedance of at least 470 KΩ. (The impedance of the magnetometer outputs is 332 Ω.)

3.2 Normal Operation

1. Power up the magnetometer.
2. Verify that the current consumption does not exceed 30 mA.
3. Orient the magnetometer such that the connector is pointing up. In this orientation, the Y arrow marked at the opposite end of the magnetometer with respect to the connector, will be pointing down. Measure the Y output of the magnetometer. The voltage must be roughly equal to the vertical component of Earth's field at that location.
4. Flip the magnetometer such that the connector is pointing down. Verify that the voltage of the Y output is roughly equal to the voltage measured in step 3 and opposite in polarity.
5. Orient the magnetometer such that the X arrow is pointing down. Measure the X output of the magnetometer. The output in nanoTesla must be roughly equal to the vertical component of Earth’s field at that location.
6. Flip the magnetometer such that the X arrow is pointing up. Verify that the voltage of the X output is roughly equal to the voltage measured in step 5 and opposite in polarity.

7. Orient the magnetometer such that the Z arrow is pointing down. Measure the Z output of the magnetometer. The output in nanoTesla must be roughly equal to the vertical component of Earth's field at that location.
8. Flip the magnetometer such that the Z arrow is pointing up. Verify that the voltage of the Z output is roughly equal to the voltage measured in step 7 and opposite in polarity.

4. Theory of Operation of Fluxgates

The typical fluxgate magnetometer consists of a "sense" (secondary) coil surrounding an inner "drive" (primary) coil that is wound around permeable core material. In the three types of sensors (ring core, racetrack and rod) currently manufactured by Billingsley Magnetics, are magnetic core elements that can be viewed as two carefully matched halves. An alternating current is applied to the drive winding, which drives the core into plus and minus saturation. The instantaneous drive current in each core half is driven in opposite polarity with respect to any external magnetic field. In the absence of any external magnetic field, the flux in one core half cancels that in the other and the total flux seen by the sense coil is zero. If an external magnetic field is now applied, it will, at a given instance in time, aid the flux in one core half and oppose flux in the other. This causes a net flux imbalance between the halves, so that they no longer cancel one another. Current pulses are now induced in the sense winding on every drive current phase reversal (or at the 2nd, and all even harmonics). This results in a signal that is dependent on both the external field magnitude and polarity.

There are also additional factors that affect the size of the resultant signal. These include the number of turns in the sense winding, magnetic permeability of the core, sensor geometry and the gated flux rate of change with respect to time. Phase synchronous detection is used to convert these harmonic signals to a DC voltage proportional to the external magnetic field.

High quality low noise fluxgates typically use a feedback loop to keep the core at zero field. The typical topology is shown in the Block Diagram. The phase synchronous detector (or analog multiplier) is utilized to detect the even harmonics and these signals are integrated in an analog integrator to develop a voltage that represents the ambient field through the core. This signal is then fed back to the core to "null" the core to zero.

The following paragraphs detail the level of complexity involved in the drive current circuit and at each step of the sense signal processing.

4.1 Oscillator/Drive Circuit

To produce fluxgates with very low noise and stable zero offsets, it is necessary to drive the sensor core deep into saturation while minimizing power consumption. The core driver usually employed consists of an oscillator/divider, a low output impedance MOSFET driver and an R/C network R2, C4 shown in the Block Diagram. The drive waveform, typically in the 10 to 30 K Hertz range, is applied to R2, C4. As the core goes through the high permeability region of the B-H curve, the impedance of the drive winding connected in series with capacitor C4 is high and the capacitor charges through resistor R2. When the core reaches saturation, the impedance of the drive winding drops to a very low value and the capacitor discharges through the core winding. A large current surge of short duration will occur in the core winding, which will drive the core deeper into saturation. On the other half of the drive waveform, the core will be saturated in the other direction.

This topology drives the core into saturation while maintaining a low average power consumption. It also ensures that the timing of the core saturation is very constant and is reasonably independent of drive voltage and core temperature effects. This timing of saturation is very important because it affects the phase of the generated second harmonic signal and it must be held constant for ideal operation of the magnetometer's synchronous detector. Any shift of the second harmonic signal phase changes the signal level, and therefore increases sensor noise.

4.2 Magnetometer Sense/Feedback Winding

The magnetometer sense/feedback winding is wound in a solenoidal form around the outside of the sensor core. This winding detects the even harmonics of the drive frequency which are proportional to the magnetic field through the sensor, and are also used to feedback a current to null the core. Dual use of the coil is possible since the harmonics are A.C. signals and the feedback is near D.C. Used as a sense coil, it is A.C. coupled via C3 to the sensor circuit's preamplifier. Capacitor C2, in parallel with the sense winding, tunes the winding whose inductance is being modulated at the core frequency by the second, and higher even harmonics of the drive frequency.

Since this coil is also used with feedback to cancel the measured field, its mechanical, electrical, and thermal characteristics are critical. The magnetometer output circuit provides feedback current to this coil, which creates a field in the opposite direction to the measured field, canceling the measured field at the sensor core. If the feedback current and the current to field relationship of this coil is known, then the field being measured is known. This coil's dimensions must not change with temperature, or must change in a predictable way, since the field it creates is a function of its dimensions and its input current.

4.3 A. C. Amplifier

The operational amplifier selected for the A.C. preamplifier has very low noise at the frequency of operation of the magnetometer circuit. Its wide bandwidth is necessary to prevent phase shift of the harmonic signals, which can cause an unstable sensor zero offset. The, A.C. coupled, gain of this stage is typically > 30 dB and reduces the D.C. errors of the following integrator stage by this amount.

4.4 Synchronous Detector

A synchronous detector is used to convert the harmonic signals from the sense coil to a D.C. voltage that is proportional to the integral of the even harmonic's magnitude. The voltage sign indicates the signal's phase. This switch must have low noise and low feedthrough of the switch's controlling signal to prevent unwanted sensor offsets.

4.5 Integrator

The amplifier used in the magnetometer circuit's integrator must have low 1/f noise as well as low current/voltage offsets and drifts. The integrator output is fed back to the sensors signal winding through a resistor. This feedback nulls the ambient field as seen by the sensor. The sensor's non-linearity is reduced by the "open loop" gain factor (typically > 100 dB) of the integrator amplifier.

Appendix

T F M 100G2

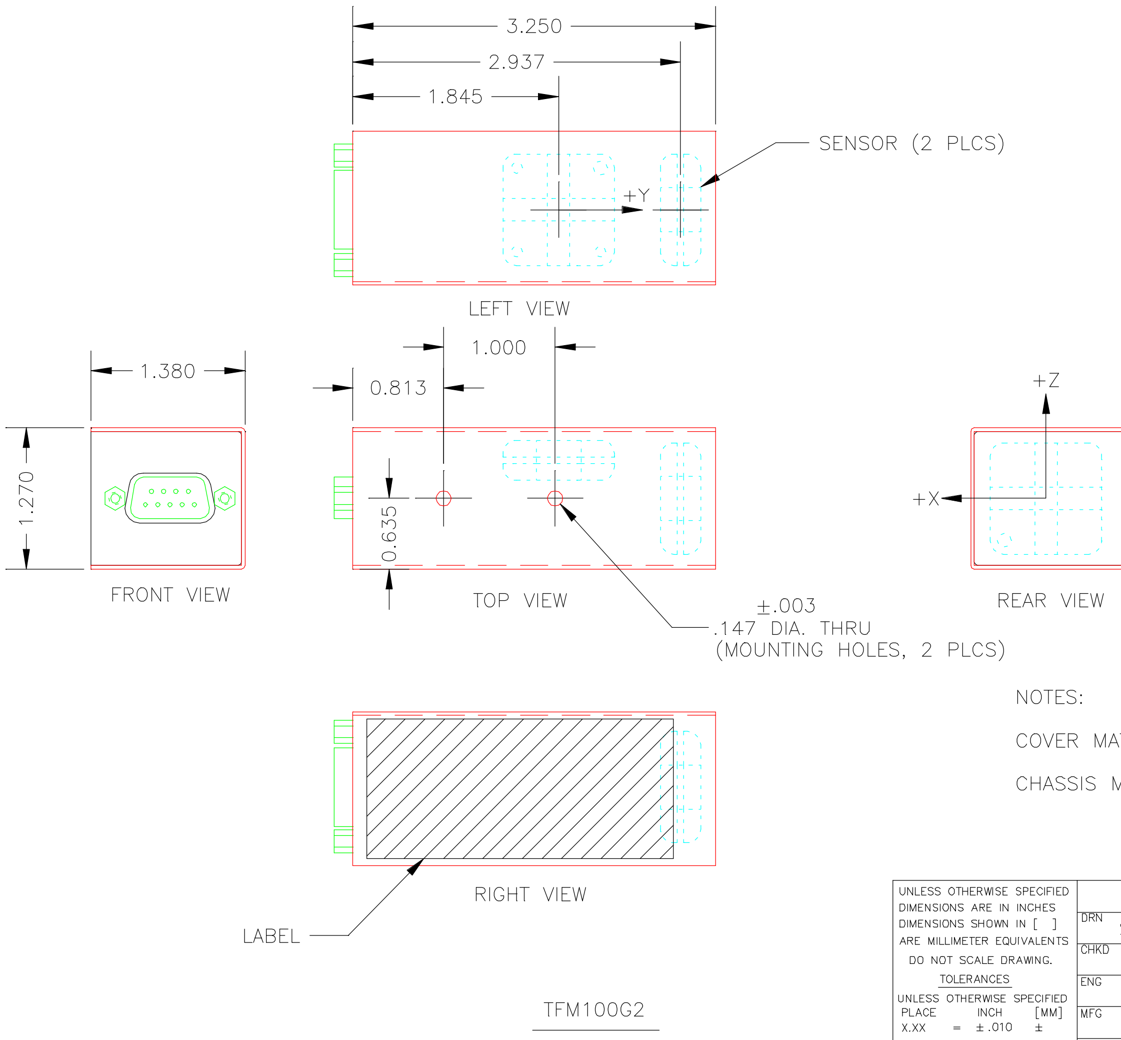
ULTRA MINIATURE TRIAXIAL FLUXGATE MAGNETOMETER

SPECIFICATIONS

Ultra Miniature Triaxial Fluxgate Magnetometer for spacecraft attitude control, general magnetic measurements in the laboratory or field applications such as remotely piloted vehicles, data buoys, sounding rockets, etc. This instrument is designed for the highest reliability and uses no fuses, potentiometers or switches.

Axial Alignment :	Orthogonality better than ± 1°
Input Voltage Options :	15 to 34 VDC @ 30mA
Field Measurement Range Options :	± 100 μ T = ± 10V
Accuracy :	± 0.75% of full scale (0.5% typical)
Linearity :	± 0.015% of full scale
Sensitivity :	100 μV/nT
Scale Factor Temperature Shift :	0.007% full scale/ ° Celsius
Noise :	20 picoTesla RMS/ Hz @1 Hz
Output Ripple :	3 millivolt peak to peak @ 2nd harmonic
Analog Output @ Zero Field :	± 0.025 Volt
Zero Shift with Temperature :	± 0.6 nT/° Celsius
Susceptibility to Perming :	± 8 nT shift with ± 5 Gauss applied
Output Impedance :	332 Ω ± 5%
Frequency Response :	3 dB @ > 500 Hz (to > 4 KHz wideband)
Over Load Recovery :	± 5 Gauss slew < 2 milliseconds
E M I :	Designed to meet CEO1, CEO3, REO2, CS01, CSO2, CSO6, RSO1, RSO2, RS03
Random Vibration :	> 20G RMS 20 Hz to 2 KHz
Temperature Range :	- 55° to + 85° Celsius operating
Acceleration :	> 60G
Weight; Size :	100 grams; 3.51 cm x 3.23 cm x 8.26 cm
Connector :	Chassis mounted 9 pin male "D" type; mating connector supplied

REV.	DESCRIPTION	DATE	APPROVED
A	PRODUCTION RELEASE		
B	REDESIGNED		
C	UPDATED		



CONNECTOR PIN ASSIGNMENTS

PIN 1: +POWER IN
PIN 2: TEMP MON (OPTION)
PIN 3: SIGNAL GROUND
PIN 4: POWER GROUND
PIN 5: Z OUTPUT
PIN 6: X OUTPUT
PIN 7: CHASSIS GROUND
PIN 8: Y OUTPUT
PIN 9: −POWER IN (OPTION)

NOTES:

COVER MATERIAL: .031" THICK ALUMINUM SHEET, 5052−H32

CHASSIS MATERIAL: .063" THICK ALUMINUM SHEET, 5052−H32

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DIMENSIONS SHOWN IN [ ] ARE MILLIMETER EQUIVALENTS

DO NOT SCALE DRAWING.

TOLERANCES

UNLESS OTHERWISE SPECIFIED

PLACE		INCH	[MM]
X.XX	=	±.010	±
X.XXX	=	±.005	±
ANGLE	=	±1 DEG.	

CAGE CODE: 0ZBN4

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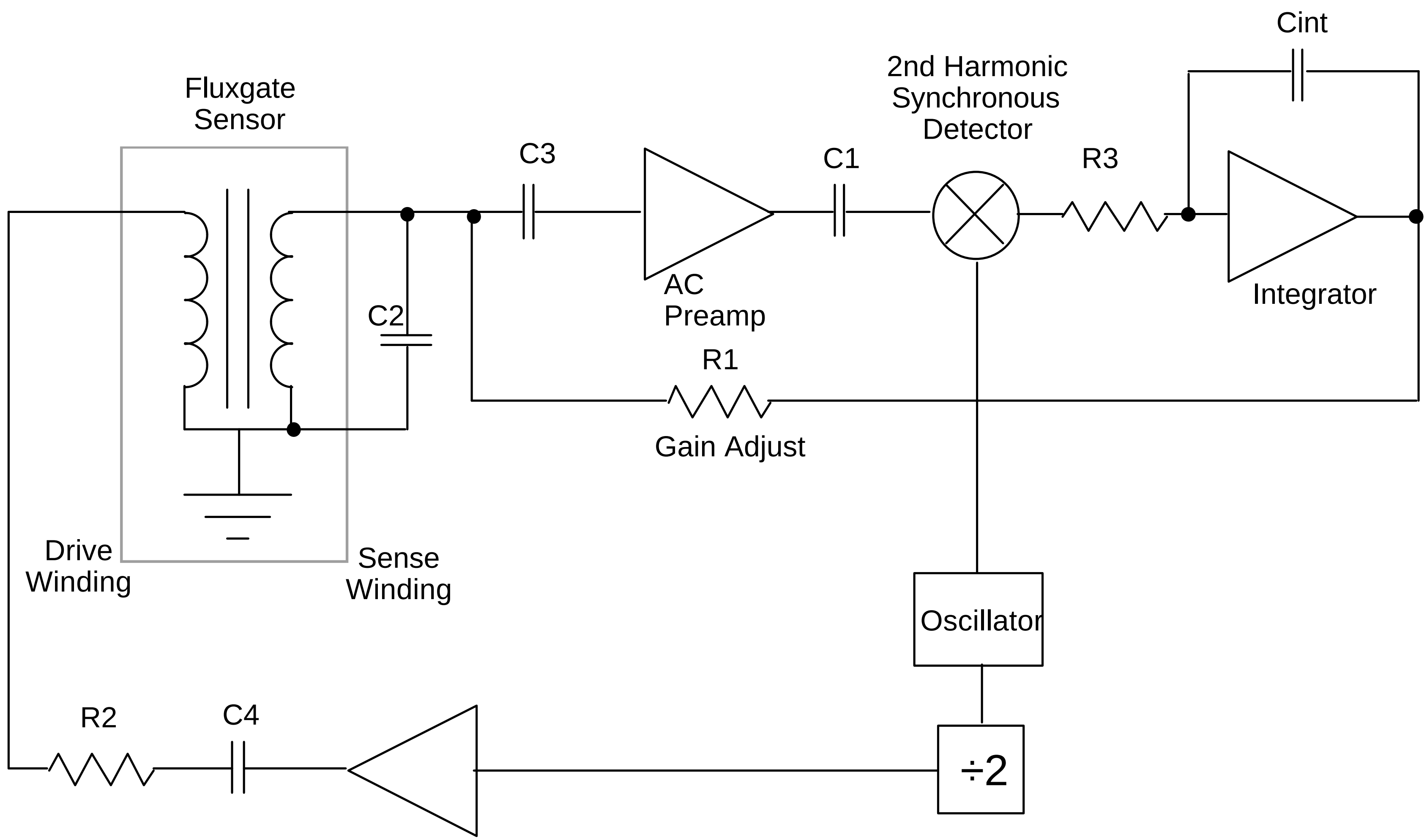
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