Gyration

Application Notes
For
GyroPoint Technology

Includes Application Notes for:

MicroGyro 100
GyroPoint ASIC

DE00053-001 Revision 1.20

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1. The MicroGyro 100

1.1 Background / Overview

In June 1997, Gyration, Inc. announced its new generation dual-axis rate gyroscope, MicroGyro 100, designed to be a high performance, more reliable and more cost-effective alternative to conventional consumer rate gyroscopes. Although it has been optimized for input devices, remote controls and game controllers — it can also be used in navigation, robotics, control systems, Virtual Reality, 3-D and other applications that sense and report movement. MicroGyro 100's unique single-stamping design offers high reliability and low manufacturing cost. It features low voltage operation with a 2.2 volt minimum. Extremely low current consumption is enhanced by a low current sleep mode.

The MicroGyro detects rotational movement (pitch, yaw and roll around the x, y and z axes). Its sensing element is a unique non-contact tuning fork or metal beam—which is vibrated by a miniature magnet/coil drive system. When the MG100 is rotated, the beam responds according to the Coriolis effect and that effect is measured and reported in voltage corresponding to the rate of rotation. When there is no rotation, unwanted signals are subtracted, so that external noise components or vibrations have no affect on the final output.

MG100 is powered by a DC voltage input and has analog signal outputs which report motion tracking information. It offers a voltage supply range of 2.2 to 5.5V, allowing it to work directly off of two AA batteries. The sensor's layout and highly automated fabrication process provide a low-cost, easily assembled, high-volume solution. The compact package design and light weight also allow design flexibility in integrating the sensor into a final product.

Features

Small, lightweight	Low power consumption
Stable	Mass manufacturable / low cost
High precision	Adaptable design capabilities
Low maintenance, long lifetime	Easy installation

1.2 MicroGyro Summary

The MicroGyro 100 senses rotation about two of any three possible axes (roll, pitch and yaw). Simply put, by measuring voltage on the output pins of the MicroGyro, the motion of the object containing the gyro can be measured and tracked. The integration of two gyroscopes into a single package allows you to easily design an intuitive pointing device for controlling objects in two dimensional space such as a TV screen, a computer screen, or a video game. When used in combination with Gyration's GyroPoint ASIC, the MG100 provides full-digital, low-power two-axis motion tracking for easy interfacing with microprocessors. The information obtained from the MicroGyro 100 can also be used to cancel out unwanted motion in an application, such as camcorder image stabilization or antenna stabilization (e.g. maintaining a constant vector for an antenna on a ship that is pitching and rolling).

The MicroGyro 100 has two rate-sensitive axes that are mounted such that the sensitive axes are orthogonal to each other. Each of these axes will give an analog voltage output that is proportional to the rotational turn rate about that axis. This proportional constant is known as the axis SENSITIVITY (SE) or SCALE FACTOR. The MG100 has a sensitivity of roughly 1.1 mV/(deg/sec) which means that a sense axis voltage will change 1.1 mV when the gyroscope is rotated around that axis at a rate of 1 degree per second. [Refer the MicroGyro 100 Specification sheet, DE00019-001, for the actual sensitivity specification.]

1.3 Electrical Issues

1.3.1 Power and Ground

The MG100 has one power pin, VCC, and one ground pin, GND. It consumes very little power for an inertial sensor, typically less than 6mA but always less than 10mA (see I_PWR in the MG100 specification, DE00019-001).

You should follow basic analog circuit design principles when putting the MG100 into a circuit. Although it has internal bypass capacitances built-in, you should plan for a 0.1uF bypass capacitor between VCC and GND on your board. Also make sure the ground plane in the area around the MG100 is as large as possible, as with any analog circuit component.

Finally, note that the gyro outputs will vary somewhat with variations in VCC. That is, the analog outputs of the gyros will change if VCC changes. The specification value for this is OFFVC. Note, however, that you would need VCC variations on the order of ±1 volt to see any real change in the output. So if you control VCC to ±5%, you will not see any measurable effect on the gyro.

The MicroGyro 100 will operate to all its specifications with a VCC voltage as small as 2.2 V. This allows you to power the MicroGyro 100 using only two AA batteries. The low voltage requirement, in conjunction with the low current consumption makes MicroGyro 100 ideal for integration into many applications where precise motion tracking, low power consumption and portability are important functions.

1.3.2 Analog Outputs

The MicroGyro 100 reports its two-axis rotational sensing in the form of two differential analog outputs. “Differential” is used here in the classical sense; meaning that to get a valid measurement of a gyro sense axis you must take the difference of two analog voltages.

The raw analog output for the first gyro axis is:

OUTPUT_1 = VG_1 - VREF_1

and the raw analog output for the second gyro axis is:

OUTPUT_2 = VG_2 - VREF_2

VREF_1 and VREF_2 are reference voltages which remain approximately constant. VG_1 and VG_2 are rate sensitive so their voltages will change in response to applied rotations around the corresponding axis.

Do not measure the analog outputs (VG_1 and VG_2) without the reference voltages; such a “single-ended” measurement will not work as intended.

These analog signals are quite precise, and good analog engineering practices should be observed in handling them if you need the full precision of the gyro. For some applications such precision may not be necessary. But for more demanding requirements, make sure that these four analog output traces are:

- short,
- ringed with analog ground,
- buffered, if the signal must travel through any length of trace or cable more than a few centimeters (refer to the OCL_REF and OCL_VG parameters in the MG100 specifications for more information on these limits)
- kept away from noisy signals, especially anything noisy in the passband of your measurement cycle.

One note, the VREF_1 and VREF_2 pins are wired together inside the MG100. It is not necessary to use both since they are electrically the same. Both pins are presented for compatibility with older technologies.

If you power on the MG100 and look at the rate outputs when the gyroscope is held motionless, then you have determined the offset for the gyroscope.(OFF) This parameter is important because it provides a reference measurement that provides the baseline from which you can detect motion.

So with no motion on the gyroscope, we measure

$$OFF1 = VG\_1_{\text{(with gyro held still)}} - VREF1$$
$$OFF2 = VG\_2_{\text{(with gyro held still)}} - VREF2$$

From this reference, you can calculate the current rate of rotation of the MG100 in your application. The key specification here is <u>SE</u>, the sensitivity of the MG100. It is specified in millivolts per rotational degree per second, or mV / DEG / s.

As noted above, the MG100 reports the rate and direction of turn (angular velocity), not the actual angular position. So the difference between VG_1 and VREF_1, in millivolts, is proportional to the rotational turn rate around that axis.

Suppose, in your application, you choose the first gyro axis to be Yaw and the second axis to be Pitch. If we let Ω represent a turn rate (in degrees per second) , then we can write

$$\Omega_{yaw} = [(VG\_1 - VREF\_1) - OFF1] / SE$$
$$\Omega_{pitch} = [(VG\_2 - VREF\_2) - OFF2] / SE$$

Since <u>SE</u> is roughly 1mV / deg / sec (actually, it is more; see the <u>SE</u> value in the specification), this works out to roughly one degree of rotation per second for each millivolt of difference voltage measured on the differential output pair. Note that we have subtracted off the OFF1 and OFF2 voltages to determine the net the voltage change was caused by the motion of the gyroscope.

1.3.2.1 Turn Rate vs. Turn Angle

If your application needs to measure the angular displacement (i.e. the net turn angle, instead of the turn rate) , you can achieve this by integrating the output voltage. A simple technique is to sample the rotational turn rate in equal intervals and then multiply the current gyro output by the sample time spacing. This is an approximation that works extremely well in applications like computer mice. So if you sample the gyro axis every 2mS, the change in the gyroscope's angular displacement (Δθ) between samples is:

$$\Delta\theta_{Yaw} = 2mS * \Omega_{Yaw} = 2mS * [(VG\_1 - VREF\_1 - OFF1) / SE]$$

$\Delta\theta_{Pitch} = 2mS * \Omega_{Pitch} = 2mS * [(VG\_2 - VREF\_2 – OFF2) / SE]$

Thus, by summing all the net angle changes between samples, you can keep track of the total angle change for each axis.

1.3.3 Sleep and Wake

The VCC power to the MG100 can be toggled for power savings. That is, when you are not sensing movement, you can drop VCC to save battery power in a portable system. Be aware, however, that the MG100 does have a few seconds of turn-on "settling" time. During this time the gyros are warming up to their equilibrium state and will read slightly differently from the normal "on" state. The relevant specifications for "normal" operation are:

OFF, the differential output voltage or "offset" when the device is not rotating;

and the specifications pertaining to the turn-on period are:

Tset, the power-on settling time;

TOD1, TOD2, TOD3; which determine at what point in time the gyros have stabilized to within a certain amount of their equilibrium state.

Refer to the actual specification for the exact values; however, a good rule of thumb is that the gyros are stable within about 5 seconds of power-on.

If you don't want to cycle VCC, you can also power-down the gyroscope bye pulling the WAKE pin within 0.5V of ground. This is the sleep mode control pin. In sleep mode, the MG100 takes only a trickle current, typically less than 3 microamps. During sleep mode, the sensitive axes are turned off, so all the concerns about turn-on settling noted above will apply when the gyroscope is awoken from sleep mode . However, the WAKE pin is a CMOS input, so it can be driven with a simple gate. Cycling VCC requires a full 10mA (max) drive with stable characteristics, so the WAKE pin may be more convenient.

The WAKE pin is active-high, so to wake up the gyroscope from sleep mode you would apply a voltage to the WAKE pin that is within 0.5 V of VCC (Do not allow the WAKE voltage to exceed VCC). The relevant specifications for this pin are I_SLP, the trickle current into VCC during sleep mode; I_IN, which is the input leakage current for the WAKE pin; V_LO, which is the WAKE pin logic low voltage needed to assert sleep mode; and V_HI, which is the WAKE pin logic high voltage needed to wake up the gyros.

1.3.4 Temperature

Like many sensing devices, the MG100 varies slightly with temperature. For many applications, such as computer input devices, remote controls and game controllers, this temperature-induced drift can be ignored. It works out to perhaps a few degrees of rotation per second in the worst case of extreme temperature shifts during operation, so if your application can safely ignore this much drift then you don't need to be concerned with temperature compensation.

If you do need temperature compensation, here are some points to consider:

The most important parameter of the MicroGyro 100 that varies with temperature is the zero point offset (OFF) because this voltage provides the reference for 'no-motion' from which all other motion tracking measurements are derived. The temperature characteristic of the OFF for a specific gyro is almost perfectly linear over the operating temperature range. Thus, if you know the slope of OFF vs. temperature, then you can zero almost all of the error associated with this temperature dependence.

The slope of the OFF with change in temperature is specified as the offset temperature coefficient (OFFTC). The OFFTC is typically around ±0.2 mV / °C for most MicroGyro 100 axes but can be as large as ±1.0 mV / °C for others.

For the maximum accuracy and lowest drift in a MicroGyro 100 application you need to characterize the OFFTC so that you can cancel these temperature-induced errors. This brings up the question of measuring the temperature. As this is a common requirement, the MG100 includes a temperature sensor. This is the purpose of the TEMP pin, which is another analog output. This output is single ended output referenced relative to ground.

The temperature sensor pin gives a nominal output voltage around 0.96V at room temperature. [Check the T_**AMB** specs for the actual voltage and its tolerance] This voltage will decrease as the surrounding temperature increases and vice versa. The proportional constant which relates TEMP output voltage to the actual temperature is the **T_TC** specification in the MicroGyro 100 specification. By measuring the voltage on the TEMP pin and multiply by the proportional constant T_TC, you can calculate the actual temperature using the equation.

$$T(\text{actual } ^\circ C) = (T\_AMB - TEMP) / T\_TC + 20$$

This calculation is usually not necessary. Instead, it is usually easier to build a table which maps the TEMP output voltage to the gyroscope sensitive axis offset (OFF) at various temperatures.

The typical way to make temperature measurements is to “soak” the application in a hotter or colder environment for a period of time. That period of time depends on your application. If you have a lot of insulating materials surrounding the MG100, it will take a longer time to heat up the MG100 itself if it is sitting in a warm oven. You can determine the optimum “soaking” time by measuring the temperature output of the MG100 and watching to see when the TEMP voltage stabilizes.

Suppose you are calibrating the gyro offsets and TEMP pin voltages at two different temperatures and you build the following table:

Actual Temperature (°C)	TEMP Voltage	OFF1 Gyro 1 Offset	OFF2 Gyro 2 Offset
22	0.964	18	-7
32	0.919	21	-9

From the table above, to achieve the maximum precision of motion tracking in your application, you would subtract 3 mV from the ‘1’ axis offset for every 45 mV decrease in the TEMP voltage output. Similarly, you would add 2mV to the ‘2’ axis offset.

1.3.5 Use of the MicroGyro near R.F. transmitters

The MicroGyro may be used in handheld devices that include radio frequency transmitters. When this is the case, care must be taken to isolate the high-frequency radiation from the MicroGyro. When the sensitive analog circuits within the MicroGyro are subjected to significant R.F. energy, then errors may couple onto the signal outputs of the MicroGyro. The R.F. energy may produce AC noise on the outputs due to aliasing and / or coupling of the high-frequency radiation. There may also be shifts in the output offsets due to rectification of R.F. energy. Here are some potential problem scenarios and suggested solutions:

Problem	Cause	Possible Solution
A 49 MHz radio transmitter and the MicroGyro are used in a portable handheld cursor control device. It is observed that as the user's hand gets close to the transmitting antennae, the output of the gyro changes, causing the cursor to drift. It is found that the position of the user's hand changes the R.F. radiation output from the antennae. The radiation output from the antennae is found to couple into the sensitive circuits within the MicroGyro, causing a D.C. shift in offset which depends on the strength of the radiation.	The tip of the antennae is very close to the MicroGyro, and the R.F. energy is coupling into the MicroGyro due to this close proximity.	Modify the locations of the antennae and MicroGyro to increase the physical distance between them. Ideally, the antennae is in the front of the product, and the MicroGyro is toward the rear of the product.
	The metal can on the MicroGyro forms 5 sides of a shielded box. The bottom of the MicroGyro is plastic, however, and there is the potential that R.F. energy could couple through it.	Add grounded metallization to the application P.C. board beneath the footprint of the MicroGyro. This effectively completes the 6th side of a shielded box, and R.F. isolation is enhanced.
	The signal output traces between the MicroGyro and the Pointer ASIC (or other A / D converter) may act as antennas which pick-up R.F. energy and conduct it back into the inside of the MicroGyro.	Keep the MicroGyro signal output traces as short as possible, and keep them isolated from interference sources.
	Part of the radio design includes an inductor that does not have a closed magnetic circuit. The high-frequency magnetic energy is able to couple into the MicroGyro, causing errors.	Replace the inductor with a shielded type inductor, or one that has a closed magnetic circuit.
In a battery powered product, a battery boost circuit is used in order to provide 5 volts to the system microprocessor. When testing the prototypes of this product, it is found that the operation of the booster circuit causes noise and offset shifts on the MicroGyro outputs.	Part of the battery boost design includes an inductor that does not have a closed magnetic circuit. The high-frequency magnetic energy is able to couple into the MicroGyro, causing errors.	Replace the inductor with a shielded type inductor, or one that has a closed magnetic circuit.

1.4 Mechanical issues

1.4.1 Mounting Issues

The suspension system internal to the MicroGyro 100 isolates the internal sensing elements from the outside world. This allows you incorporate the MicroGyro in your application without worrying about how the mounting conditions will affect the sensor performance. However, this isolation is not 100%. There are some small errors than can be induced in the gyro axes as you change its outside mounting condition.

1.4.1.1 Stiffness

Overview

The MicroGyro must be mounted properly to avoid error caused by coupling of external vibration with the beams internal to the gyroscope.

Rule of thumb: To minimize error associated with the mounting condition of the gyroscope, you should place in a position where the mounting condition is stable. In other words, if the MicroGyro 100 is soldered into a PCB, you should avoid twisting or bending that PCB

The MicroGyro 100 has been tested for this sensitivity. In this test, the gyroscopes are mounted to a firm surface and these results are compared to another measurement where it is allowed to rest freely on a very soft surface. This test reports the measured difference on the gyroscope outputs under these two conditions, summarized in the table below.

Mounting Condition, Typical Effect on MicroGyro Output

MS	Mounting Stiffness Sensitivity	Gyration Stiffness Test, Hard to Soft	0.3	mVPP

1.4.1.2 Orientation Sensitivity

Overview

The output of the MicroGyro 100 may vary slightly as its orientation changes with respect to gravity.

Effect on MicroGyro Output

The following table shows the typical change in output of the MicroGyro 100 when it is put through the Gyration Cube Test. In this test, the offset (OFF) of the gyro is measured for six possible mounting orientations (each of the six faces of a cube). The output is the variation in the offset seen throughout the duration of this test. Although the orientation sensitivity of the MG100 is usually measurable, it should be less than 1 mV of error in the worst case
.

OS	Orientation Sensitivity	Gyration Cube Test, 6 orientations relative to gravity	0.9	mVPP

1.4.1.3 Mounting – Sensing Orientation

The MicroGyro 100 senses 2 of 3 possible rotational degrees of freedom (Yaw, Pitch and Roll), depending on the mounting orientation.

Application Notes

Orientation

The two axes of the MicroGyro 100 are depicted in Figure 1 below. From the diagram, it can be seen that when the MicroGyro is mounted horizontally (pins facing down), Axis 1 will sense Yaw. In this horizontal configuration, Axis 2 will sense either pitch or roll, depending on the orientation.

In a vertical mount configuration, Axis 1 will detect Pitch, and Axis 2 will detect either Yaw or Roll, depending on the orientation (assuming the vertical PCB is parallel to the z axis).

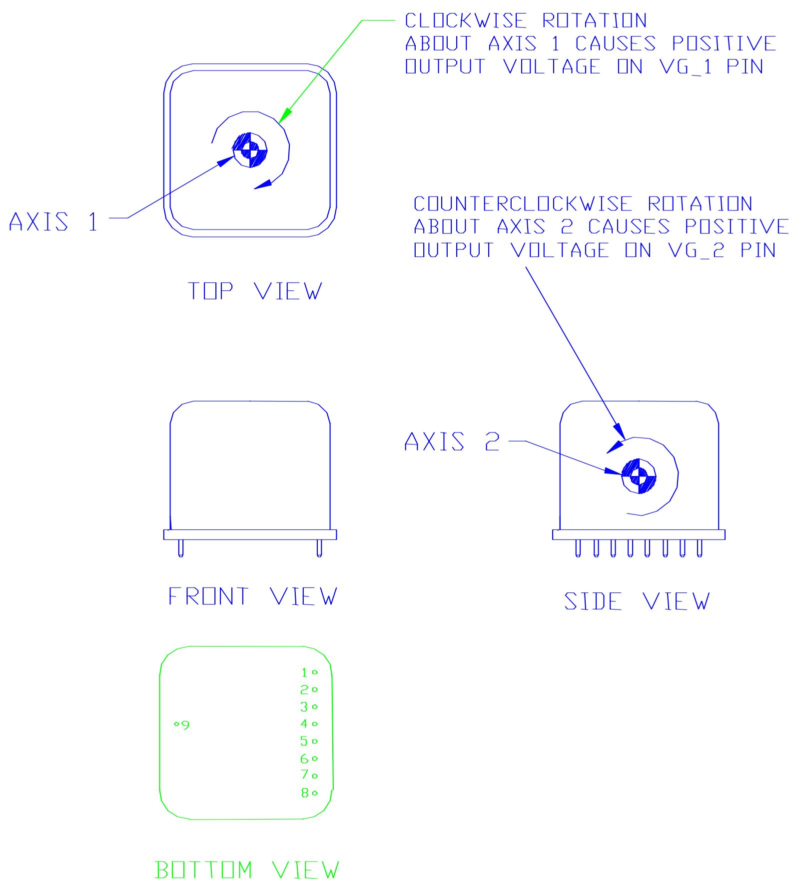
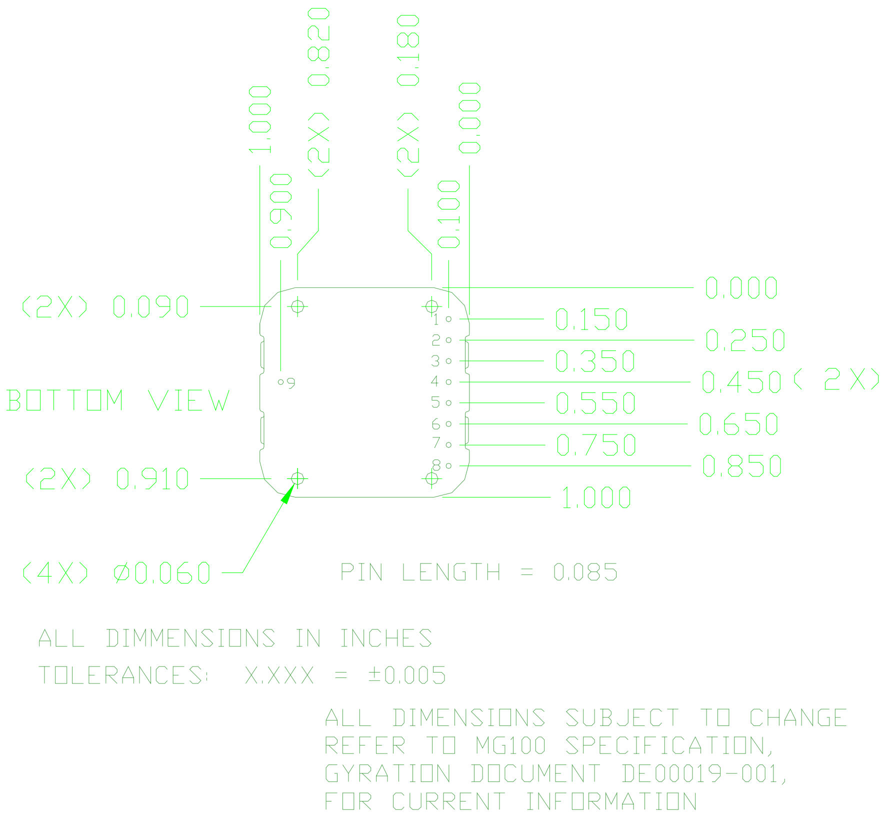


Figure 1: MicroGyro 100 Sensing Orientation

1.4.2 Footprint

All of the MG100 output pins are situated on 0.100” centers, so that its pin locations are compatible with many existing prototype hole patterns and grids for integrated circuits. Refer to Figure 2 below for the footprint diagram.



PIN	NAME
1	VREF_1
2	VG_1
3	GND
4	VCC
5	VREF_2
6	VG_2
7	WAKE
8	TEMP
9	N.C.

Figure 2: MicroGyro 100 Footprint

1.4.3 Vibration Susceptibility/Audible Frequency

The resonance of the internal suspension system of the MicroGyro 100 is 20Hz to 30Hz. Application vibrations between 10Hz and 50Hz should be avoided as they can mechanically excite the gyro suspension structure resulting in an increasingly non-linear output, starting at an input amplitude of about 0.25G (peak).

Application vibrations between 1000 Hz and 2000 Hz should also be avoided, as this is the range of the drive and sense frequencies of the inertial beam element of the MicroGyro 100. The slight high-pitched audible sound that can barely be heard from the MicroGyro 100 is at the two beam's operating frequencies at about 1400 Hz and 1900 Hz.

PLEASE NOTE: Applied vibrations in these frequency ranges will not damage the MG100 but will cause temporary nonlinearities in its output. When the mechanical vibration stimulus is removed, the gyroscope will return its normal operational state within 0.3 seconds.

1.4.4 Linear Acceleration and Shock

Between 2-3 G of DC linear acceleration are required to overcome the internal suspension of the MicroGyro 100 and cause the internal structure to hit the crash stops. This acceleration level, therefore, defines the DC acceleration operating limit for the MicroGyro 100.

The maximum shock rating (survivability, not operational) is 1000 G peak, using an 11 mSEC half sine pulse (refer to specification, DE00019-001).

1.4.5 Temperature Extremes

1.4.5.1 Storage

The MicroGyro 100 may be safely stored at temperatures from –30 to +85 degrees C

1.4.5.2 Operational

The operational temperature range of the MicroGyro 100 is –5 to +45 degrees C. At the extremes of this temperature range, between –5 to +5 degrees C and +35 to +45 degrees C, the MicroGyro may display slightly degraded performance. Please refer to the following characteristics in the MicroGyro 100 specification: SE, OFFTC, TOD1, TOD2 and TOD3.

1.4.6 Cross-Axis Sensitivity

Cross-axis sensitivity is a phenomenon that occurs in any translation or rotation sensor, in which a small fraction of movement along or about one axis will cause a small output on a different axis. For example, pure Pitch movement applied to the gyroscope case may cause a slight shift in the output of the Yaw. This is due to a slight mechanical misalignment of the rate sensitive axes to the gyroscope's external case.

The Cross-Axis Sensitivities for Axis 1 and Axis 2 (see Figure 1 on page 10) are reported in the table below. Note the Axis 3 is not sensed by the MicroGyro 100, but is the third possible rotational axis (orthogonal to Axes 1 and 2):

Sensing Axis	**Applied rotation on Axis 1**	**Applied rotation on Axis 2**	**Applied rotation on Axis 3**
Alignment Error to Axis 1	N / A	~ 2°	~ 1°
Alignment Error to Axis 2	~ 4°	N / A	~ 0°

1.4.6.1 Example

Assume the MicroGyro 100 is mounted such that Axis 1 senses Yaw and Axis 2 senses Pitch. The gyro is rotated purely in Pitch at a rate of 10 degrees / second. The Cross-Axis Sensitivity (CAS) error on the output of Axis 1 is as follows:

CAS = (10 degrees / sec) X (1.11 mV / degree / sec) Sin(2°) = 0.387 mV

Note that this is a known value, and may be compensated for either digitally in software or in an analog circuit.

The voltage output on the pitch axis will be what you would expect to see

Vpitch = (10 deg / sec)*SE
= 11.1 mV

Adding the CAS correction to the yaw output, we can zero out this small error

$$Vyaw(unadjusted) = 0.387\ mV$$
$$Vyaw(adjusted) = Vyaw(unadjusted) - CAS \approx 0$$

1.5 Manufacturing issues

1.5.1 Handling

Handle with care. Do not drop or apply any strong impact on the sensor.
Do not immerse MG100 in fluid (pre-clean PCB)

1.5.2 Washing

If washing is necessary, refer to the following table. Do not submerge the sensor during wash. Use an external and local application of wash only.

Base Solvent	Example	Available
Chloride base	Trichloroethane	OK
Fluorine base	Freon (TF, TES, TE)	OK
Water base		OK
Alcohol base	IPA, ethanol	OK
Others	Gasoline	No

1.5.3 Soldering

The MicroGyro 100 is a finely tuned electromechanical sensor and will not withstand some soldering condition extremes that many integrated circuits can withstand. For this reason, we offer the following recommended guidelines, to be followed in addition to good soldering practice.

1.5.3.1 Flux application

Use non-corrosion rosin, and alcohol base solvent with little chemical reaction. Apply the flux thinly so that it will not to intrude into the sensor. Do not use a dip application of flux.

1.5.3.2 Solder material

JIS Z 3238, H60A or H63A

1.5.3.3 Solder Temperature

Do not exceed 250°C

1.5.3.4 Soldering time

Within 5 seconds, to avoid conduction of excessive heat into the sensor

1.5.3.5 Cooling

In order not to cause sensor deterioration by the soldering heat, cool down by air blow immediately.

1.5.3.6 Desoldering

If you need to desolder the MicroGyro 100 from a printed circuit board, it is important that you follow these procedures or you could damage the sensor.

For the fastest removal time, we suggest using a forced hot air gun with a special nozzle or a soldering iron tip that allows you to heat all 9 pins simultaneously. Do not heat the pins for more than 5 seconds and do not exceed 250°C.

1.6 3-Axis Sensing

1.6.1 Requirements

MicroGyro100 (2X)
GyroPoint ASIC (1X)
Differential Amplifier (Op Amp w/ 6 Resistors, about $0.30 in low volume)
Customization of firmware for microprocessor

1.6.2 Implementation of 3-axis sensing

A single MicroGyro 100 can sense two rotational degrees of freedom, therefore two MG100 units are required to sense all three possible axes.(Yaw, Pitch and Roll) In this configuration, the two gyroscopes will provide 4 axes of rotational sense but one axis will be redundant.

The GyroPoint ASIC has an internal multiplexor with 4 connections to an A/D converter, allowing you acquire digital data from up to 4 analog inputs. In our 3-axis sensing scheme, we use utilize 3 of these 4 inputs.

However, of these four ASIC inputs, only 2 have built-in differential amplifiers with gain. Therefore, an additional discrete differential amplifier needs to added for amplifying for the third sense axis to the same levels as the other two axes.

The firmware for the microprocessor must be expanded to process three axes.

1.6.3 Two Gyros –Mounting Conditions

When using two MicroGyro 100's in the same application, you will need to provide some isolation between the two gyroscopes to avoid vibration interaction. If possible, the gyros should be mounted to separate, stable mechanical references. If you want to mount two MicroGyro 100 gyros onto to the same PCB, this PCB should have adequate thickness and the two gyros should be positioned as far from each other as possible. The addition of mounting details local to the gyros (e.g. screws located next to the gyros) will also help minimize the possibility that the two MG 100s will interact.

2. GyroPoint ASIC

2.1 Function and Benefit

The MG100 provides analog rate outputs giving precise two-axis motion tracking. In order for these rate signals to be utilized in a larger, more intelligent system, these analog signals usually must be converted into digital signals.

The GyroPoint ASIC was specifically designed to accomplish this task. The GyroPoint ASIC provides all of the necessary circuit elements necessary to interface the gyro's analog rate signals with a microprocessor. The entire ASIC typically uses only 650 microamps and it can be put into a "power-down" mode where it draws only 25 microamps making it perfectly suited for use in low power devices.

The GyroPoint ASIC combines the following circuit functions into a single package.

1. 4- Channel 12 bit Dual Slope Analog-to-digital converter
2. Serial Interface for controlling input commands and extracting digital data from the ASIC
3. Buffers for interfacing with a number of platforms, including PS/2, Serial Port, and Macintosh ADB
4. Very low-current "power-down" mode

2.2 Electrical Issues

Minimum Connections

Figure 3 below shows the basic connections for using the MG100 with the GyroPoint ASIC:

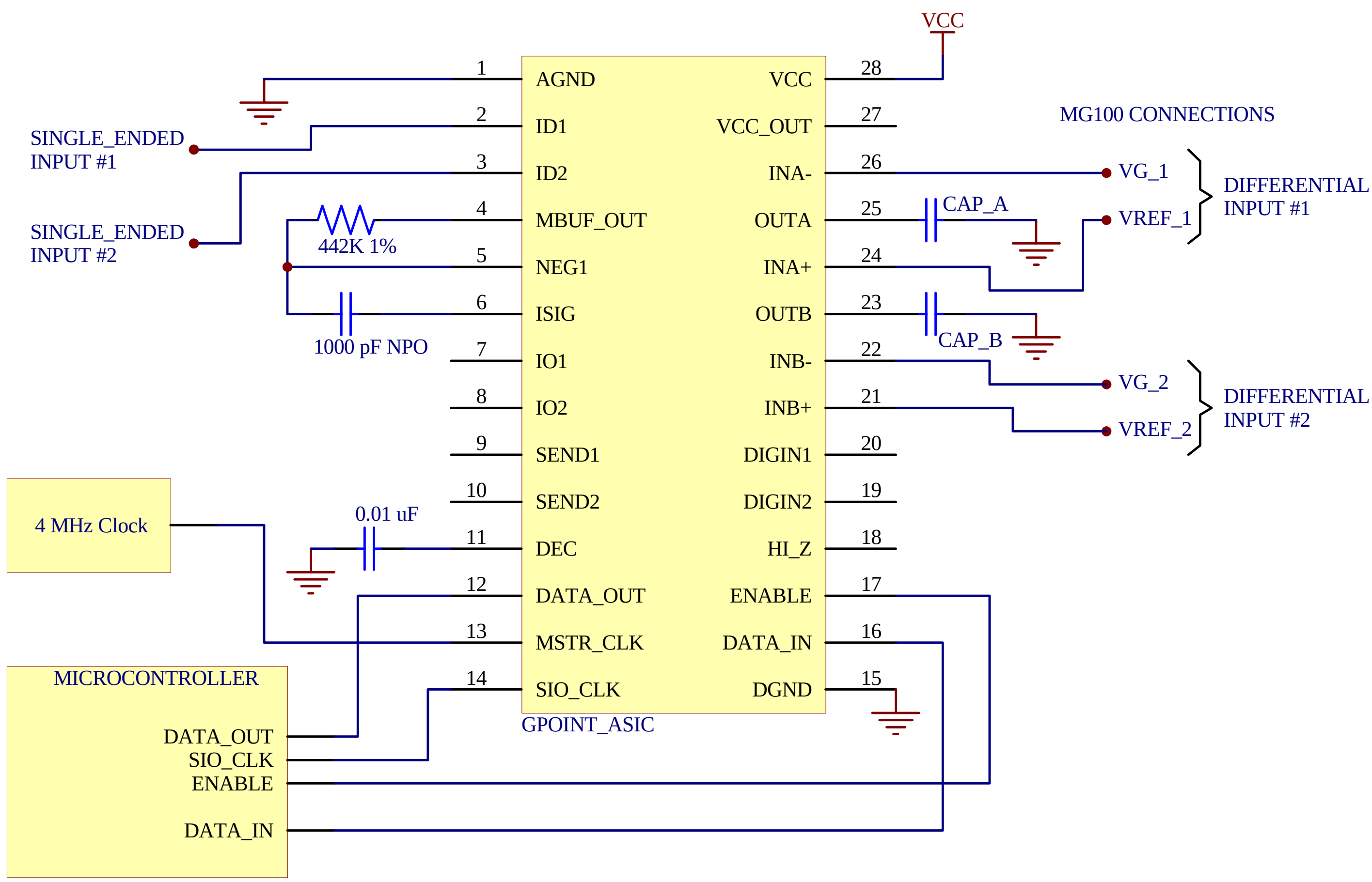


Figure 3: GyroPoint ASIC Pin Diagram

Note that the 442K and the 1000 pF capacitor provide the time constant for the Full Scale resolution of the A / D converter when running the master clock at 4MHz. The values of these two components may be changed slightly but the product of R and C must remain a constant for the ASIC to work properly. If the master clock runs at a lower frequency, then the RC time constant should be increased using a linear scale to adjust for the slower clock operation. Also, for the best performance of the GyroPoint ASIC over temperature, you should use resistors and capacitors with low temperature coefficients.

2.2.1 Signals

The GyroPoint ASIC allows you connect up to four analog inputs that will then be available for digital conversion. Please refer to Figure 4 below which shows the layout of the GyroPoint ASIC in block form.

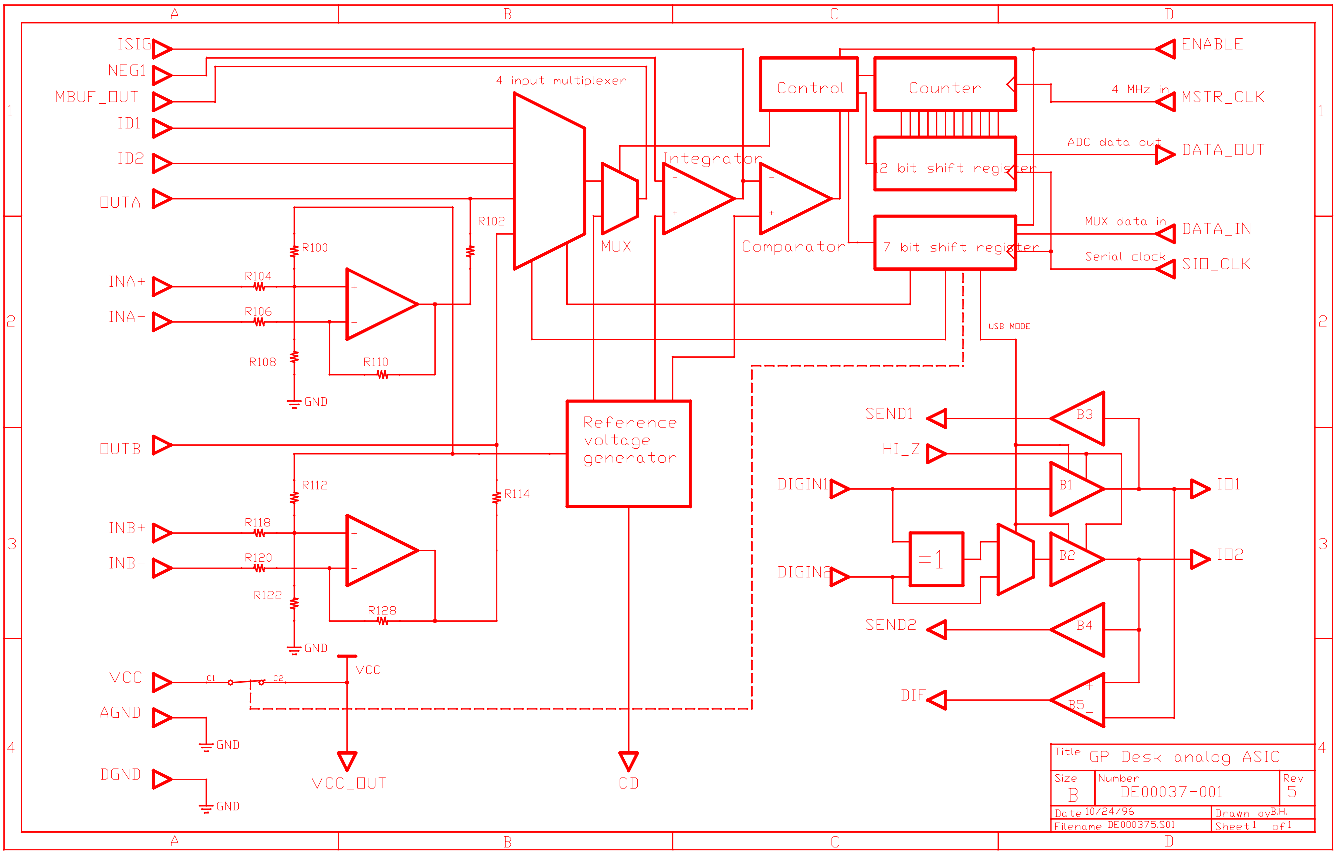


Figure 4: GyroPoint ASIC Block Diagram

There are two different types of analog inputs that the GyroPoint ASIC can accept.

1. **Differential Analog Inputs** (**INA+/-** , **INB+/-**) - These inputs have a differential input range of ±0.375 V and are amplified and buffered inside the ASIC. These two differential input pairs are specifically designed for connecting to the two MG100 analog rate outputs. You can connect the two differential outputs of the MicroGyro 100 directly into these inputs.
   - The **INA+** and **INB+** inputs are designed to accept fixed reference voltages only. To avoid amplifier non-linearity, please connect only the MG100 **VREF_1 and VREF_2** outputs to these pins.
   - The dynamically varying gyroscope ouputs **VG_1** and **VG_2** should connect to either the **INA-** or **INB-** input.
   - The **OUT_A** and **OUT_B** pins are filter taps on the INA+/- and INB+/- channels after analog amplification but before digital conversion. The series resistors on the amplifier output (R114 and R102 shown in Figure 2) are 100K. By attaching capacitors to the **OUT_A** and **OUT_B** pins you can provide additional filtering to the analog signals, thereby greatly improving the signal-to-noise ratio of your data.

2. **Single Ended Analog Inputs** (**ID1**, **ID2**) - these inputs have an input range of 0.5 - 2.0 Volts and are not amplified or buffered.

The single-ended inputs are intended for general use to allow you to acquire other analog information along with the MicroGyro 100 outputs. For example, the MicroGyro100's built-in temperature sensor can be connected to one of these inputs if you want to collect and store the temperature as a part of your application.

2.3 ASIC Control

The GyroPoint ASIC has a four-wire serial interface for controlling its functions. To control the GyroPoint ASIC's internal circuits, you shift in a 7 bit control word into the DATA_IN pin on the ASIC. However, since most microprocessors work in units of 8 bits (or more), one will usually add additional bit(s) to the least significant bit (LSB) position of the control word and set those bit(s) to zero.

For Figure 5 below, we have added to single bit to the LSB side, making our input an 8-bit control word.

SHIFT THIS BIT IN LAST (MSB) — SHIFT THIS BIT IN FIRST (LSB)

MSB							LSB
SELECT CHANNEL INA+/-	SELECT CHANNEL INB+/-	SELECT CHANNEL ID1	SELECT CHANNEL ID2	POWER DOWN CTRL	BUFFER CTRL	START A/D BIT	0

Figure 5: GyroPoint ASIC Input Control Word

2.3.1 Control Word Bit Definitions

SELECT CHANNEL INB+/-
SELECT CHANNEL INA+/-
SELECT CHANNEL ID2
SELECT CHANNEL ID1

These first four bits allow you to select which analog input is to be presented to the 12 bit converter. To select an input, set that input's select bit to '1' and the remaining 3 channel select bits to '0'.

START A/D BIT

If you wish to start an analog-to-digital conversion, this bit is set to 1.
Otherwise, set this bit to 0.

POWER-DOWN CTRL

This bit allows you to shut off the GyroPoint ASIC to minimize current consumption during times when you are not using the GyroPoint ASIC's functions.
0 = Setting during normal ASIC use
1 = Power-Down the GyroPoint ASIC

BUFFER_CTRL

0 = Setting for normal use of the ASIC's DIGIN1 and DIGIN2 buffers
1 = This bit should be set to 1 for "power-down" mode

Based on these definitions, we can make the following table showing valid command words and their functions.

8-bit Control Word Examples (x = means Don't Care)

Action	**Control Word**
Start A/D Conversion on Channel INA+/-	10000x10
Start A/D Conversion on Channel INB+/-	01000x10
Start A/D Conversion on Channel ID1	00100x10
Start A/D Conversion on Channel ID2	00010x10
Perform No Operation	00000x00
Power Down the GyroPoint ASIC	00001100
Normal Buffer Operation	xxxxx0x0

IMPORTANT NOTE :You should note that some combinations of control bits should be avoided

For example:

00110X10 will start an analog to digital conversion, but with two inputs (ID1 and ID2) shorted together at the converter's inputs, leading to unexpected results. For best results, make sure your microprocessor code does not issue such control words.

2.3.2 Timing

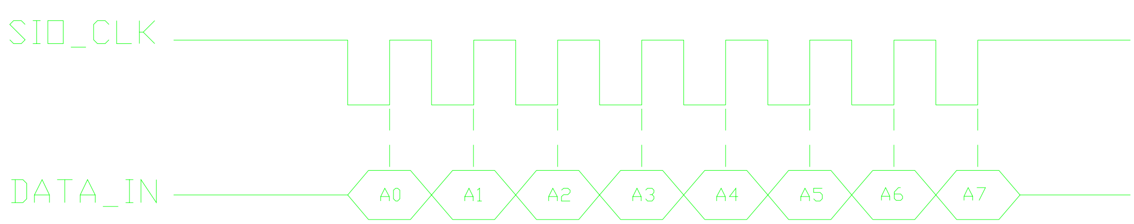


Figure 6: GyroPoint ASIC Timing Diagram

Figure 6 above shows the required timing relationship between the SIO_CLK line and the DATA_IN line when sending an 8-bit control word A ={ A7 A6 A5 A4 A3 A2 A1 A0} to the GyroPoint ASIC. Note that the DATA_IN pin is read on the RISING edge of the SIO_CLK pin.

2.4 Completing an analog-to-digital conversion

****

*****   VERY IMPORTANT   *****

****

Once you have started a A/D conversion, you should wait for that the conversion to finish before you issue another any new control words or try to read the conversion value. Failure to wait for the conversion to complete will result in errors in the values you read.

To complete a conversion you should use the following steps

1.) Raise the **ENABLE** input pin HIGH
2.) Apply a clocking signal on the **SIO_CLK** line, and simultaneously shift the desired control word into the **DATA_IN** pin (Remember LSB goes in first; MSB goes in last)
3.) Pull the **ENABLE** input LOW
4) Wait a minimum of 8192 Master Clock cycles (the GyroPoint ASIC Master Clock)
5.) Raise the **ENABLE** input pin HIGH
6.) Apply a clock signal to the **SIO_CLK** line, and simultaneously shift 12 bits (or more) from the **DATA_OUT** pin of the ASIC to some memory location in the microprocessor. [Optional: You can shift a new control word into DATA_IN at the same time you are shifting out the data from the last control word].
7.) Pull the **ENABLE** input LOW and go to step 1 for the next sample.

2.4.1 Output: 12-bit words

The converted data comes out of the DATA_OUT pin as a 12-bit, 2's complement binary number with its least significant bit (LSB) coming out first. The interpretation of this 12-bit number will depend on which analog input was the source of the conversion because the inputs have different input ranges. The following table summarizes how to interpret the 12-bit number.

	FullScale Negative	**MidScale**	**FullScale Positive**
DATA_OUT value (binary)	100000000000	000000000000	011111111111
Decimal Equivalent	-2048	0	+2047
Input Channel Source ID1 or ID2	2.0 V	1.25 V	0.5 V
Input Channels Source INA+/- or INB+/-	+0.375V	0	-0.375V

Note that the scaling of the differential inputs and the single-ended inputs have different polarities and the resolution is different by about a factor of 2. A few examples should help clarify these subtleties.

2.4.1.1 EXAMPLE:#1

The 12-bit DATA_OUT number read is 000100010001 (273 decimal) and the input source was the INA+/- Channel.

Thus the voltage at the INA+/- input was
= 273*(-0.375)/(2048)
= -0.050 V

2.4.1.2 EXAMPLE:#2

The 12-bit DATA_OUT number is 111111010011 (-45 decimal) and the input source was the ID2 Channel.

Thus the voltage at the ID2 input was
= 1.25 - [(-45)*(0.75) / (2048)]
= +1.266 V

2.4.2 Input / Output: 16-bit words

For maximum efficiency in your use of the GyroPoint ASIC, you should shift in the next control word as the same time you are shifting out the digital data results from the last control word. Obviously to accomplish both these tasks in the same time window requires that you modify both word sizes to become the same size.

A convenient way of achieving this is to make both input words and output data 16 bits long. Now when you shift in a control word to the DATA_IN pin, you need to add eight additional 0's to the LSB side of the control word. The previous 8-bit control word table is repeated here to show the same command set in 16-bit format.

16-bit Control Word Examples (x = means Don't Care)

Action	Control Word
Start A / D Conversion on Channel INA+ / -	10000x1000000000
Start A / D Conversion on Channel INB+ / -	01000x1000000000
Start A / D Conversion on Channel ID1	00100x1000000000
Start A / D Conversion on Channel ID2	00010x1000000000
Perform No Operation	00000x0000000000
Power Down the GyroPoint ASIC	0000110000000000
Normal Buffer Operation	xxxxx0x000000000

The ASIC DATA_OUT format also can use 16 bits words and the ASIC output was specifically designed to allow this flexibility. As stated previously, the converted data output of the ASIC is a 12-bit 2's complement binary number, and the ASIC *will automatically repeat the sign bit for any output word sizes larger than 12 bits.*

The net result is that the output number will always be a valid 2's complement binary number provided that you use an output word size of 12 bits or more.

SAMPLING RATES
Each analog-to-digital conversion requires a minimum of 8192 ASIC master clock cycles to complete. If you are operating the GyroPoint ASIC at a 4MHz clock speed, you can achieve sample rates on a single analog input at rates approaching 488 Hz or you can sample both gyro axes up near 244 Hz.

3. Warranty

Gyration Limited Hardware Warranty

Gyration products are warranted to be free from failures due to defects in material and workmanship for a period of three months from the date of purchase. During the first three months, Gyration will, at its sole discretion, replace or repair the defective products; for out-of-warranty products, Gyration will charge a fixed fee to cover handling and service costs based on

Gyration's then-current price schedules. Gyration, at its sole discretion, may replace or repair the defective product with a then-current product having similar features and functionality as determined by Gyration.

You are responsible for packing the failed product properly for shipment and for the charges to ship the failed product to Gyration. Gyration is responsible for the charges to ship the repaired or replacement product back to you. If any charge to you is involved, the replacement product will be sent C.O.D.

If the failed product has been modified without Gyration's consent or if the failure is the result of misuse, abuse or misapplication, Gyration has no obligation to repair or replace the failed product.

Before returning a failed unit, you must obtain a Return Merchandise Authorization (RMA) number by calling a Gyration customer service representative at (408) 255-3016. The RMA number should be prominently displayed on the outside of the returned package and on the accompanying packing list. Gyration cannot be held responsible for any package returned without an RMA number or damages caused by improper packaging.

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