Speake & Co. Limited   Distributed in the United States by Fat Quarters Software
24774 Shoshonee Drive   Murrieta, California 92562 USA
Tel: 951-698-7950   Fax: 951-698-7913

FGM-series
Magnetic Field Sensors

- +5 volt operation
- Three Terminal Devices
- DC to 20 KHz Bandwidth
- Low Temperature Sensitivity
- High Intrinsic Sensitivity
- Built-in feedback coils (FGM-1 and FGM-2 only)

Description

The FGM-X series of devices are very high sensitivity magnetic field sensors operating in the ±50 microtesla range (± 0.5 oersted). They are simple, essentially three terminal devices, operating from a single +5 volt supply, the connections being ground, +5v and output. The output is a robust 5 volt rectangular pulse whose period is directly proportional to the field strength, (giving a frequency which varies inversely with the field), making it very easy to interface to a computer or micro controller. The typical period swing for the full range of an FGM-3 is from 8.5 µs to 25 µs (~120 KHz to ~50KHz), a clear indication of its high sensitivity.

The FGM-1 is essentially a miniature version of the FGM-3 with an added overwound coil and slightly lower sensitivity.

The FGM-2 is a single package containing two FGM-1 sensors at right angles to one another.

Unlike Hall Effect field sensors, which are virtually unusable in this range because of their large temperature sensitivity, the FGM-series has a very low temperature coefficient.

Since the lowest effective Nyquist sampling rate is ~50 KHz, appropriate filtering can provide an AC field bandwidth from DC to ~20kHz.

Maximum Supply Voltage	**7 volts**
Recommended supply Voltage	**5 volts ±0.5 volts**
Typical Supply Current	**12 mA**
Operating Temperature Range	**0 - 50 °C**

Typical Applications

Since the range covers the earth's field magnitude, multiple sensors can easily be arranged to provide compass orientation or full three-dimensional orientation systems, using the local earth's field as a reference, (gimballed compass or virtual reality helmet devices.)

Other applications include conventional magnetometry, earth field magnetometry, ferrous metal detectors, internal vehicle re-orientation alarm sensors, external vehicle or ship passage sensors, wreck-finders, non-contact current sensing or measurement, conveyor belt sensors or counters and in conjunction with small permanent magnets, movement and proximity sensors and ferrous impurity detectors for non-magnetic alloys.

Conventional magnetometry would include magnetic material measurement, B-H loop measurement, Preisach displays and archaeological artifact assessment.

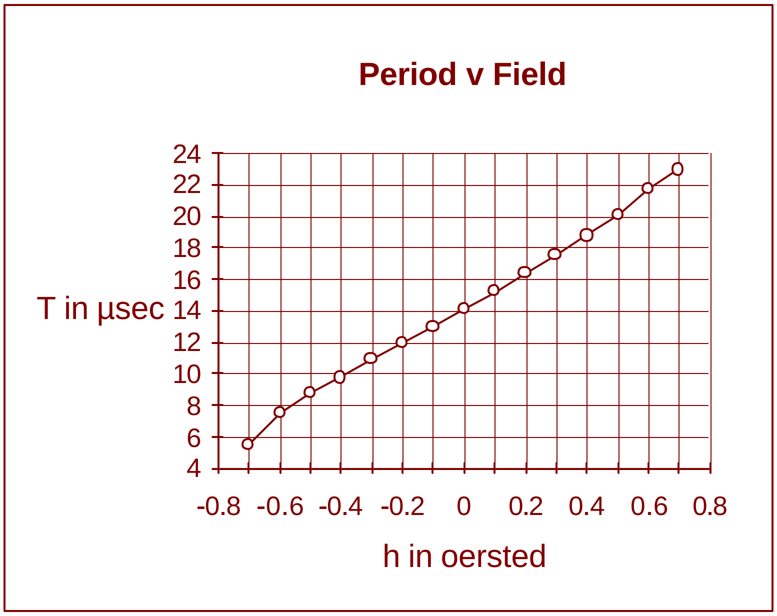
For use with applications requiring a larger range of field strength, external feedback winding techniques can increase both the sensor's maximum range and its linearity. This approach is described in more detail in the separately available "Application Notes" but basically consists of using an overwound solenoidal coil in a negative feedback loop which continuously attempts to zero the field seen by the sensor. By this means the range and the linearity cease to be a function of the sensor characteristics and depend only on the feedback current through the coil.

For added convenience, the miniature versions, FGM-1 and FGM-2, have such a coil built into their normal structure.

Output Period as a Function of Field Strength

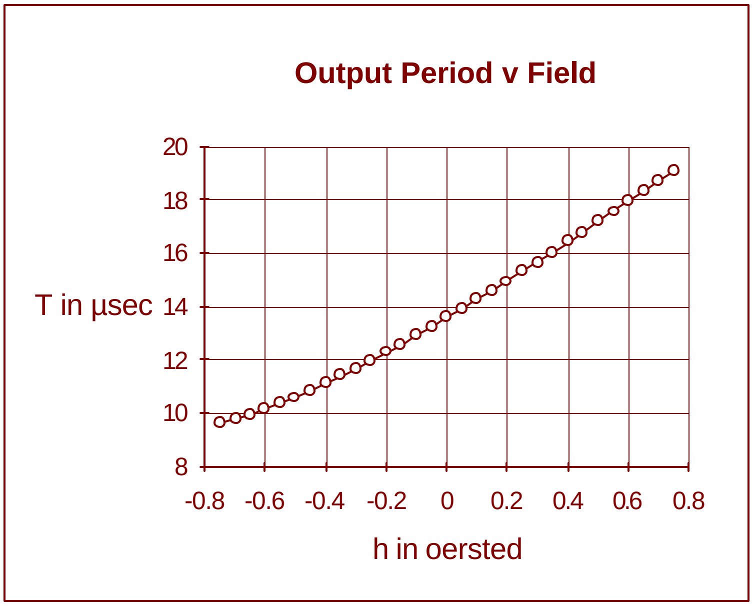
Typical Characteristics

The chart below shows the typical response of the larger size sensor of the range, the FGM-3



Between ±0.5 oersted (±50 µtesla) the non-linearity is about 5.5%.

A typical response for the miniature types of sensor, the FGM-1 and FGM-2 is given below.



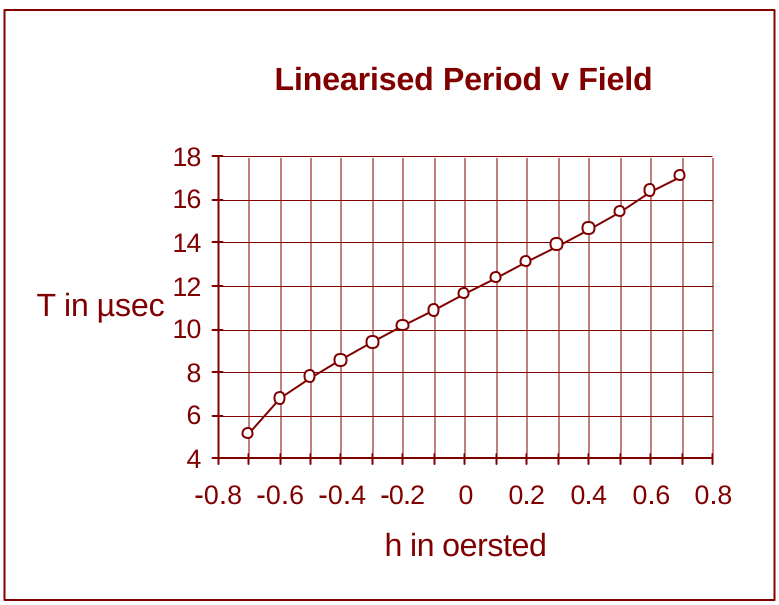
Between ±0.5 oersted (±50 µtesla) the non-linearity is about 4.8%

This non-linearity varies somewhat between individual sensors, but may normally be expected to be in the region of 5%.

A simple strategy will improve this considerably.

It was stated earlier that the field strength was inversely proportional to the frequency. In practice it will be found that the field strength is more closely inversely proportional to the frequency plus a small constant. If the frequency is measured and a fixed number of kilohertz is added before it is divided into one, to obtain the period, the response curve of period against field will be seen to become much more linear.

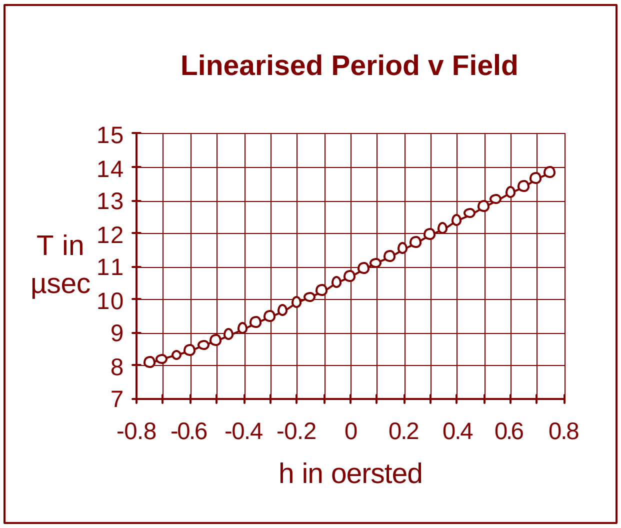
The chart below shows the effect of adding a fixed value of 15 KHz to the incoming frequency of an FGM-3 sensor before inverting to obtain the period. (Plot shows T= 1/(f+c), c=15 KHz)



Apart from the droop at -0.7 oersted the linearity has improved considerably. In fact applying the same definition as before the non-linearity between ±0.5 oersted has been reduced from 5.5% to 0.7%

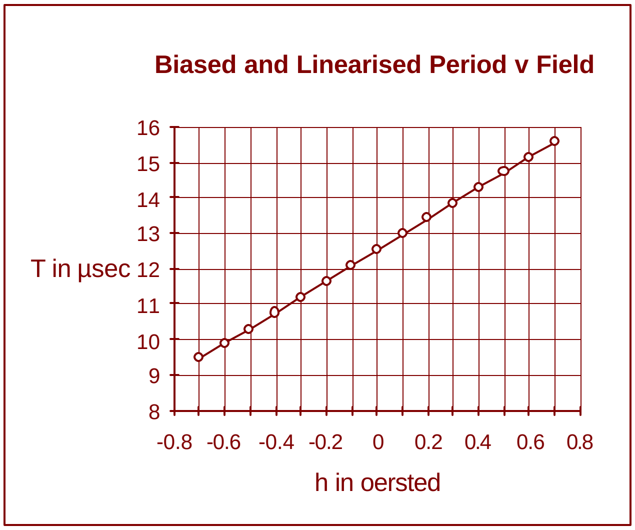
In individual cases varying the 15 KHz figure may produce an even better non-linearity, but in general this value will produce a significant improvement with any production sensor, where individual tailoring is undesirable.

The same technique can be used with the miniature sensors FGM-1 and FGM-2. The chart below shows the effect of adding a constant frequency of 18 KHz to the incoming frequency before obtaining the period by inversion. (Plot shows T=1/(f+c), c=18 KHz)



For the miniature sensors a further improvement in linearity and also maximum range can be obtained by making use of the built in overwound coil intended for feedback systems. This can also be used as a simple biasing coil to alter the zero field period of a sensor. Inspection of the graph above suggests that moving the h scale to the right might improve the linearity.

This is, in fact, the case and the effect of injecting a current of about minus 1 mA (a 4K7 resistor to a -5 volt supply) into the feedback winding pin, can be seen in the graph below.



The linear range and linearity can be seen to have improved considerably and applying the same criterion as previously, the non-linearity has been reduced from 4.8% to 0.2% across the increased range of ±0.7 oersted.

If the application is set up in such a way as to measure the period directly, rather than the frequency, followed by an inversion, the linearising technique can still be used.

The method is to use T/(T+cT) as the quantity which is proportional to field strength, where T is in microseconds and c is in kilohertz as before.

For applications requiring greater linearity, the more complex overwound external coil feedback system can provide this together with even more enhanced field strength range if needed.

Supply Voltage Variation

The period (and frequency) of the FGM-series of devices varies with supply voltage, having a coefficient of about 3.5% per volt at the nominal 5 volt supply level. For precise applications good supply regulation is required, but since the transducer's current requirement is low, this is fairly easy to achieve using, for example, single or double regulation with devices from the LM78LXX series.

General Application Notes

Use with Computers and Microcontrollers

The large pulse output gives considerable noise immunity permitting the use of transducers sited at long distances from the main system.

Interfacing is simple in that it requires only one bit of a digital input port per channel of measurement, the technique being to count input pulses for a fixed period to determine the frequency of the incoming signal, from which the field can be calculated. Alternatively, where a faster response is required, the time between successive like edges permits the direct determination of period, from which again the field can be calculated.

With microcontrollers this usually presents no problem, but with systems using many interrupts or extensive multi-tasking it may be necessary to buffer the input signals to deal with the high data rate. However this usually means no more than the addition of a single triple-counter I/O chip even for three-dimensional orientation systems.

For applications such as earth field magnetometry, where readings may only be required at relatively long intervals simple binary division with a single chip 12 or 14 stage divider will reduce the input period to a level where data rate ceases to be a problem to the computer. Alternatively, in such applications where the field variation is extremely small, digital heterodyning with a stable oscillator will also reduce the period but simultaneously maintain the high sensitivity, (in hertz/oersted) to field variations.

For applications which need absolute field magnitude without any orientation sensitivity, it is necessary to use three orthogonal sensors and exploit the fact that the sum of the squares of the three signals is constant regardless of orientation. Provided that the zero offsets, channel sensitivities and linearisation are appropriate to the required absolute sensitivity, this will permit free movement of the sensor head while measuring small changes in absolute field. If the sensor is in constant angular motion, advantage can be taken of this to provide some level of auto-calibration of zero offset and channel sensitivity. (See Application Note - Auto Calibration Algorithm .)

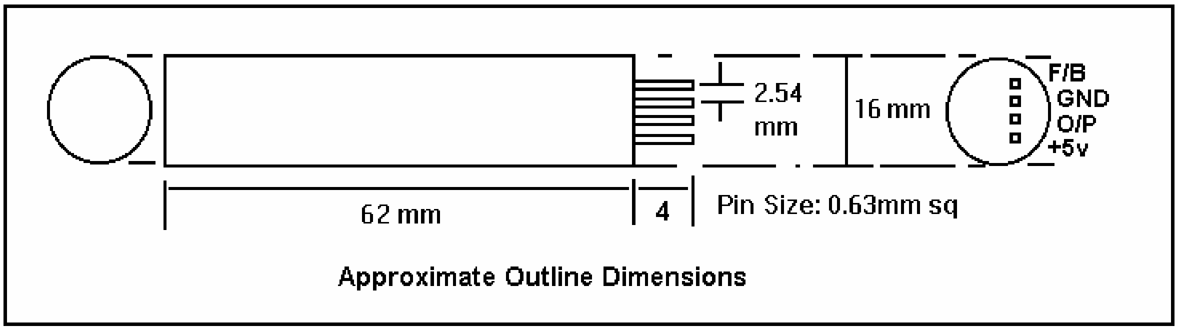
Where the sensor can be permanently fixed, only one sensor is necessary, the zero offset being adjusted to suit the local ambient field strength. This technique is appropriate to fixed ferrous metal detection systems such as conveyor belt counters, vehicle and ship passage detectors and materials magnetometry. A limit to the range of such systems results from the fact that the earth's field itself fluctuates at a low level continuously. The effective range will be a function of the size or likely magnetic moment of the objects being detected, ships generally giving a larger range than vehicles or hand guns. Appropriate filtering of the input frequency variations will enhance range.

Where extremely high sensitivity is required it may be possible to use two sensors in a gradiometer configuration to cancel out the micro-fluctuations of the earth's field. However, this will not always increase range, since the gradiometer sensitivity falls off faster with range than the simple field sensor.

In this context, it should be remembered that the field produced at range by a magnetic moment falls off as the inverse **cube** of the range, so the gradiometer configuration will fall off as the inverse **fourth** power. However such systems may be useful as short range high sensitivity detectors and materials measurement systems. An example might be extremely small magnetic moment inert particles introduced into fluid flow systems for movement detection, such as chemical processing plants or animal internal fluid flow systems in medical research applications.

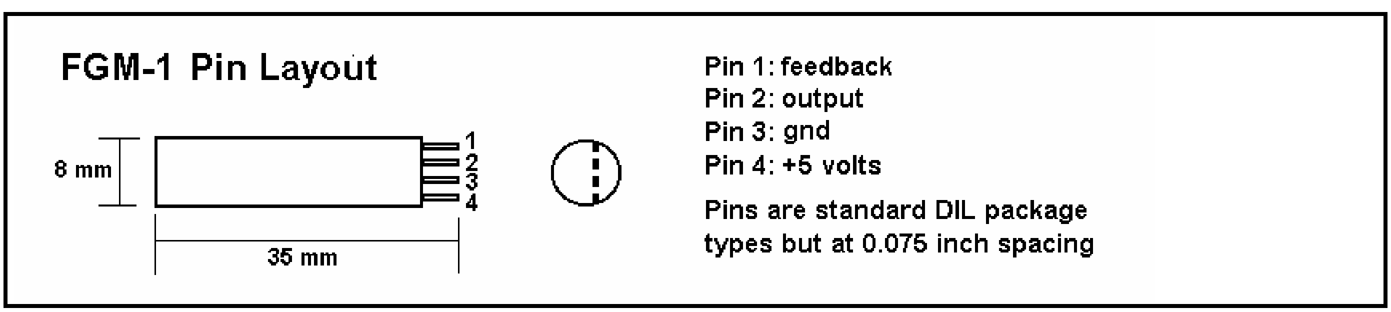
PHYSICAL CHARACTERISTICS

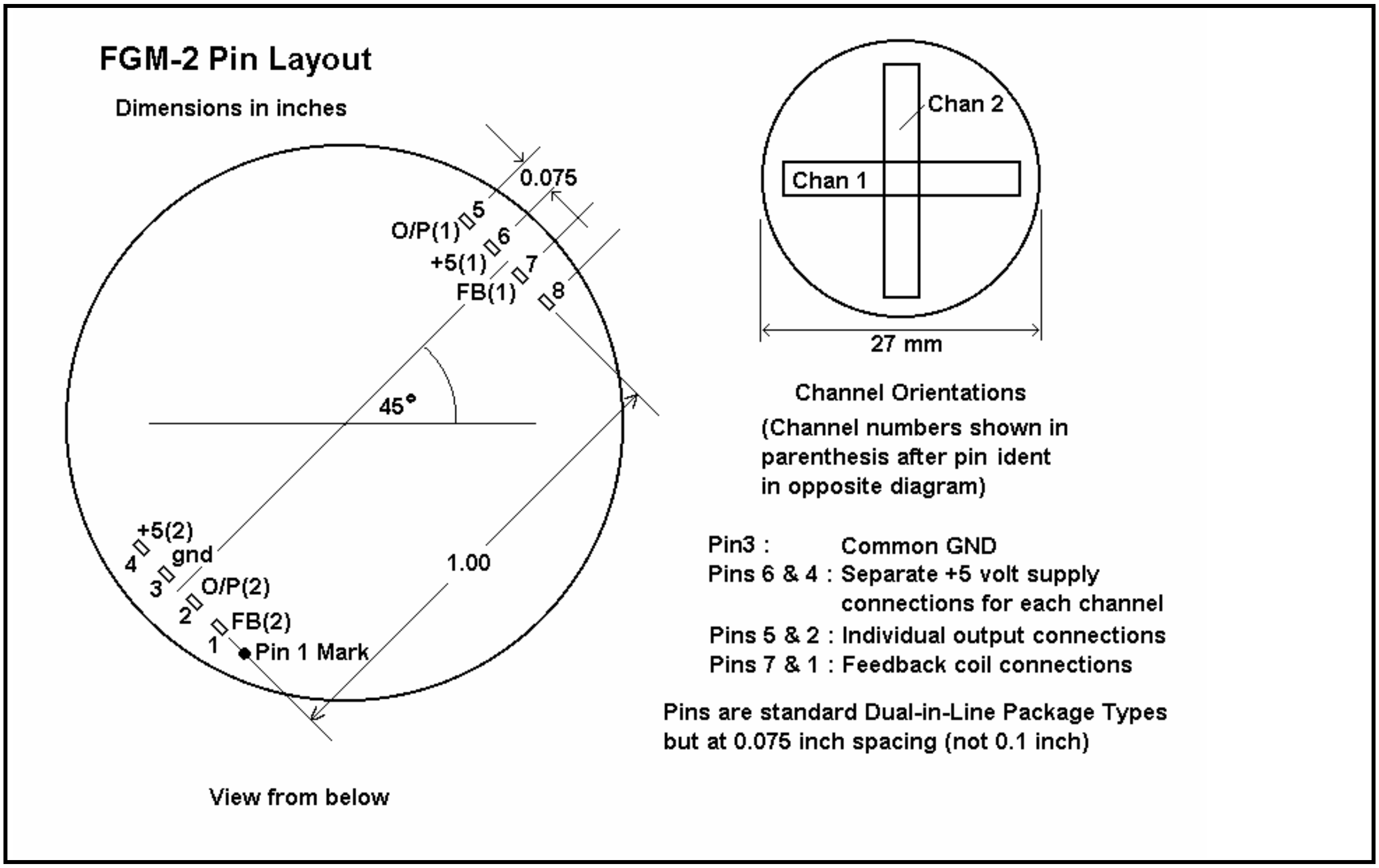
Sensor Outline - FGM-3



The sensor has been made with a cylindrical form in order to facilitate the overwinding of external feedback coils. Alternatively, it can be readily inserted into a separately fabricated coil on a tubular core.

As a simple guide, for example, a single layer of 0.2mm wire (0.25mm overall say) wound over 60mm of the sensor length will give the equivalent of 4000 turns/metre. Since 1 oersted is approximately 80 ampere-turns/metre, such a winding will produce a field of around 50 oersted/ampere. Thus with up to 100mA flowing it is possible to offset fields of ±5 oersted, increasing the range of the sensor by x10. Negative feedback also brings all the usual benefits of improved linearity and stability, of course.





CONVERSION TABLES

Magnetic Flux Density

	gauss	tesla	gamma
1 gauss	1	10^{-4}	10^{5}
1 tesla	10^{4}	1	10^{9}
1 gamma	10^{-5}	10^{-9}	1

Magnetic Field Strength

	amp/metre	oersted
1 amp/metre	1	0.01257
1 oersted	79.58	1

NOTE: Technically, the sensor measures flux density, in gauss, but since in vacuum (and virtually in air) the units of flux density are the same magnitude as those of field strength and since the sensor can only really be used in air, oersted have been used in the text and diagrams as equivalent to gauss.