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FGM-series
Magnetic Field Sensors

Application Notes

SCL001 Integrated Circuit - Magnetic Field Nulling System / Gaussmeter

This integrated circuit is designed to provide most of the functions required to provide automatic cancellation of low level magnetic field interference. The technique employs a closed loop containing a sensor to measure the local field and a magnetic field generating coil system to provide the cancellation. A typical application is the reduction of interfering fields near the neck of CRT display tubes.

The sensor and IC combination attempts to continuously adjust the coil current to maintain a near zero field strength at the sensor location. In practice the sensor cannot occupy the required zero field area since this is normally filled with the equipment needing protection. However if it can be placed close to the area, it can track a slightly non-zero field value chosen to provide the zero value where it is needed. This is done by including an adjustable offset control in the amplifier driving the nulling coils, the final trimming being carried out on the equipment in normal use.

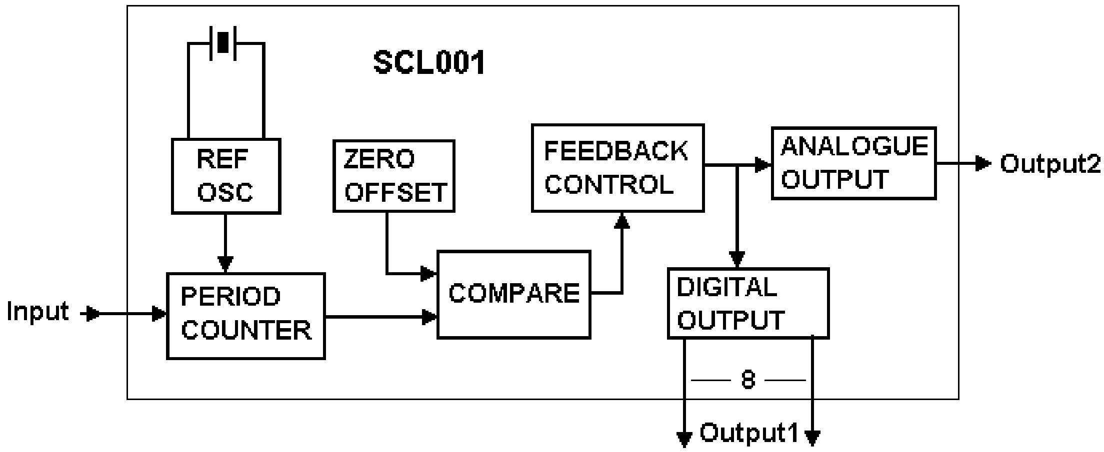
A single coil can only achieve cancellation in one direction and if the interfering field can rove over two or three dimensions, then duplication or triplication of the system may be required. Many cases can be handled by a single coil appropriately aligned and most of the rest by two coils. Some types of protected equipment may not be sensitive to fields in certain directions. Each case needs to be considered individually. Some ingenuity of coil design may be called for, but variations on the design by Helmholtz are usually possible.

The current drive requirements for such coils are usually modest since the interference has normally been restrained by other design strategies employed during equipment development.

The internal function of the SCL001 is shown in the block diagram below and consists of a reference oscillator, stabilised by an external crystal or ceramic resonator, a period counter, an offset subtractor, a feedback controller and two types of output register for control of the nulling coil current.

The period counter accumulates reference oscillator pulses between a fixed number of incoming input pulse edges to determine the period of the sensor pulses. This period is directly proportional to the field strength along the sensor axis. The count is then compared with a fixed reference in the subtractor to generate an error count. The fixed reference value is equal to the average period of production sensors in zero field. The error count is used by the feedback controller to provide a velocity feedback output to close the loop. Velocity feedback is used to help stabilise the closed loop and prevent oscillation.

The final output is presented in two alternative forms, the first being a parallel, eight bit, digital version in an offset zero format. This is basically two's complement but with the most significant bit inverted prior to output. This permits its use with a D-to-A converter and offset operational amplifier to produce a bipolar output, without the need for an additional external inverter.

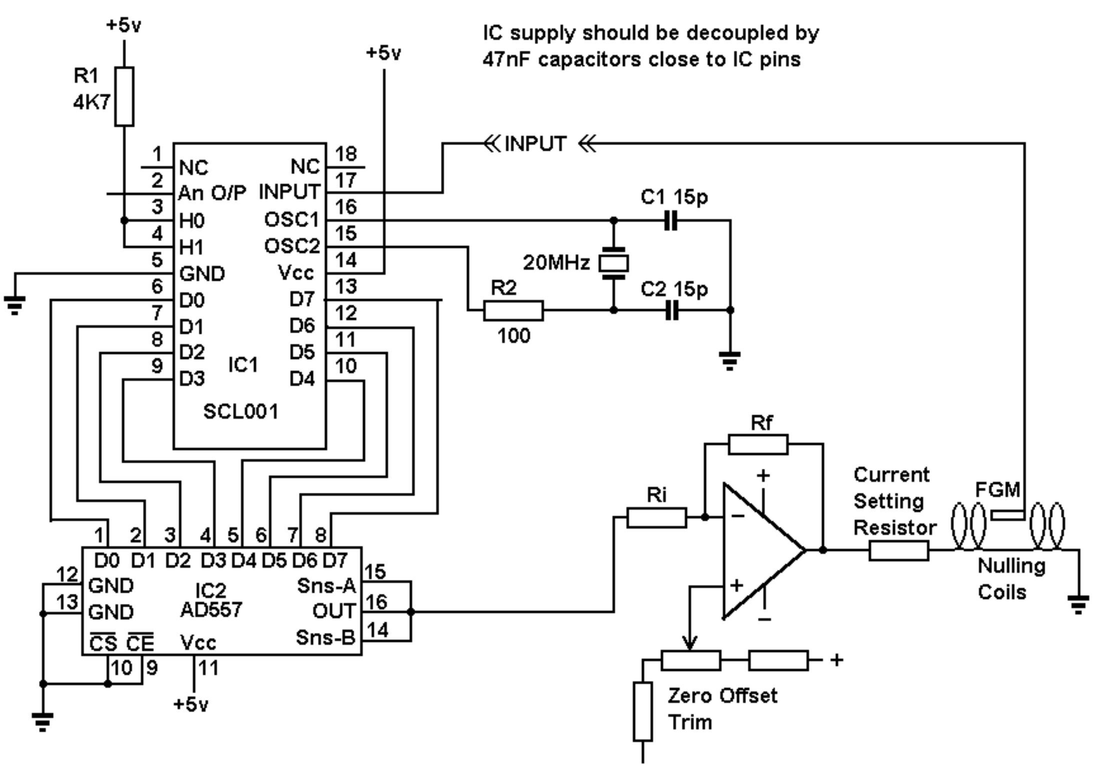


Block Diagram - SCL001

The second output is on a single pin and takes the form of a fixed frequency, variable mark-space ratio pulse. This also has eight bit resolution and is arranged so that the one-to-one ratio condition is intended to represent zero current. After low-pass filtration this again permits the use of an offset operational amplifier to produce a bipolar output.

Both types of output register have traps to prevent wrap-around causing anomalous behaviour if the interference goes outside the design range.

The rate at which the data is updated in the registers is 2450 times per second, giving the system an inherently rapid response rate.Typical application circuits are given below.

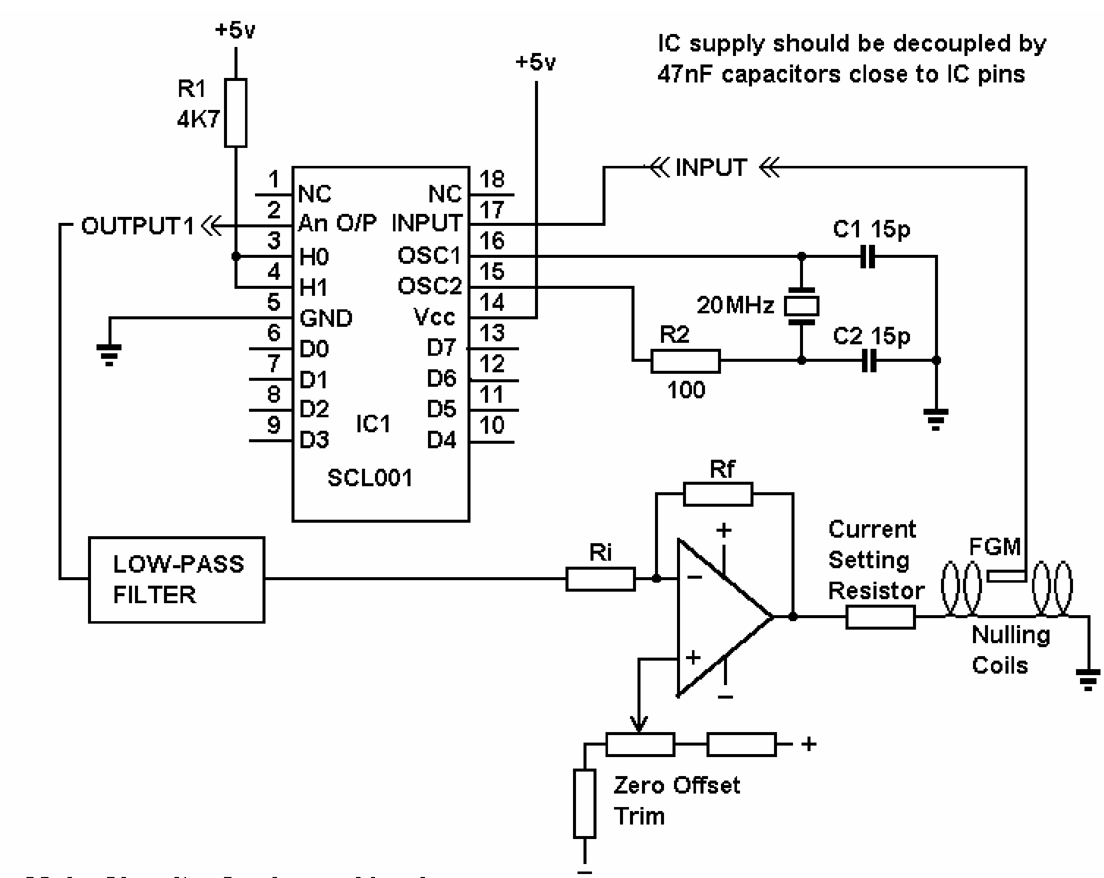


Main Circuit - D to A Version

Nulling coil design will vary considerably with the application and the ingenuity of the designer, but it is assumed in the design of the SCL001 that the field produced is a single valued monotonic function of the driving current.

The conversion of the IC output to a driving current is an external task which must also be left to the overall system designer, but can range from a simple resistor/capacitor filter and series resistor for 50 microtesla unipolar correction, to a D-to-A converter and power op-amp for very high field range bipolar correction, with more modest standard op-amp configurations in between.

The overall correction range is a function of the closed loop gain, which is most easily controlled by the choice of series resistor used to convert the output voltage to a coil current. For a calibrated coil, giving a known number of microteslas per milliampere, the resistor is selected to give the desired total field range from a knowledge of the required current and the maximum and minimum amplifier output voltages. The coil is then connected with the polarity which gives negative closed loop feedback.



Main Circuit - Analogue Version

It should be remembered however that the output resolution is limited to eight bits and high field ranges will lead to correspondingly reduced zeroing capability in the absolute sense. The interference reduction is relative and the theoretical maximum reduction is by a factor of 128 or 42 dB. In practice this is more likely to be 36 dB.

Gaussmeter Application

Although the use of this chip has so far been described in terms of field nulling techniques, it can be used to implement a modest gaussmeter.

Because the systems described so far always seek to reduce the field at the sensor to near zero, the current used to create the cancellation field is a direct measure of the local ambient field. Because of the strict proportionality of the relation between current and generated field the non-linearity of the sensor is effectively eliminated. Also, because the sensor is constrained to work always within its non-saturated range, the apparent overall range of the instrument can be increased above the ±0.5 oersted (±50 µTesla) inherent sensor range.

This provides all the ingredients to make a Gaussmeter, provided a suitable field nulling coil can be arranged. Fortunately, in this case a simple single or multiple layer solenoidal coil wound to be about the same length as the external dimensions of the sensor will suffice in most cases.

The resolution of the instrument is limited to the eight-bit precision inherent in the internal chip design, but this should still give something like a one percent resolution in both positive and negative directions.

The output can be taken directly from the digital section of the chip to feed to a computer or microcontroller or from the output of the analogue current generating amplifier for use with a meter or chart recorder.The system does not provide a guaranteed zero field calibration and some arrangement is necessary to set the amplifier zero-offset with the sensor in a known zero field area to obtain an absolute calibration. The relative calibration of sensitivity should be easier, however, in terms of the current and the known number of turns per metre of the solenoidal coil. The sensor specification data sheet gives detailed information regarding the field inside solenoidal coils and may be helpful in this respect.

SCL001HR Integrated Circuit

This is a modified version of the original SCL001 chip providing a higher resolution for those systems requiring to null more substantial field strengths. The basic operation of this chip is identical to that described in the earlier application notes, but the resolution of the variable mark/space ratio analogue output has been increased from 8 bits to 12 bits providing a much finer control of the field nulling current.

The suggested analogue field nulling circuits remain the same as those described in the previous notes. However, where large fields are involved, the increased gain required in the external feedback amplifier, results in equally large quantised steps in the correction current if the earlier 8 bit chip is used. This can lead to an undesirable hunting effect in the nulling current and even a large scale oscillation in current if the filtering time constants are not correct.

When used for field nulling in CRT display systems this can give rise to undesirable flicker in the image. The increased resolution provided by the new chip improves this situation considerably.

The penalty paid for this improvement is a reduction in response rate from 2450 Hz to one sixteenth of this or approximately 150 Hz, requiring an adjustment of the time constants used in the low pass filter used to smooth the analogue output.

Because of the restricted pin count, the previous digital version of the circuit can not be implemented and would, in any case, now require a 12 bit DAC, adding to the overall cost.

Additional Note on Overwound Coils

Where an overwound coil carrying a large current is used, it is likely that this could have a relatively small number of turns and be fed from an amplifier with a low output impedance. Such an arrangement will look like a shorted turn to the internal windings of the sensor and can result in sensor malfunction. As mentioned in the earlier application notes, the source impedance of the current driver should preferably be no less than 1K at the operating frequency of the sensor.

Since this frequency is in the region of tens of kilohertz, a small inductance in series with the overwound coil will normally achieve this impedance easily and if made by winding a heavy gauge wire on a ferrite core can still carry the large low frequency current required for field nulling. A value of 2 mH is more than adequate.

Systems used for field nulling CRT displays usually have the large field nulling coils in series with any overwound coil on the sensor itself. These coils will have sufficient inductance themselves to resolve this problem.