AN7

Separated Analogue and Digital Method for Ring Fluxgate Magnetometers

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1 Scope

This method is described for Autonnic products A407X and A408X but the method is applicable to other subsystems in particular A4051.

2 Background

While AN2 described the fundamental operations of a ring fluxgate it was AN3 which detailed particular ways for the Excitation and Sense and the following summary of the fundamental approach is taken from it:

1. It is important to eliminate parasitic resonances
2. It is important to cancel clockwise and anti-clockwise flux-leakeage from excitation to sense
3. Offsets need to be reduced
4. The signal path should be shared between X and Y

The method used by these newer devices obeys all but the last for the intrinsic reason that the continuous analogue signal has to be maintained independently for X and Y. Nevertheless, the warning given in AN3 has been remembered and care is taken to make the 2 signal paths as symmetrical as possible.

3 Implementation

3.1 Excitation

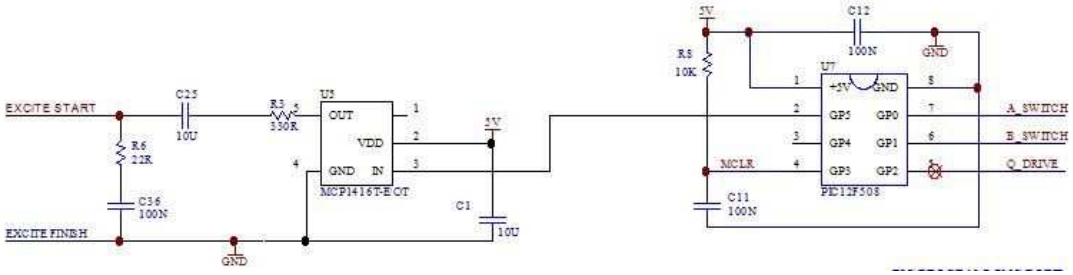

Fig 1

Fig. 1 shows the basic excitation circuit which runs continuously. Although it used a microprocessor for the generation of waveforms this is purely for convenience, cost and circuit board area considerations.

U7 is programmed to generate a square wave on GP5 which is fed to a mosfet gate drive device U5. The low impedance drive of U5 has R3 and C25 in series with the excitation winding to control the rate of change of both voltage and current of the excitation drive. First of all, C25 means that there can never be net DC in the excitation windinbg and so there is no steady field generated to cause magnetic detection errors. Rule 1 (of section 2 above) is obeyed by the inclusion of R6 and C36 which act as a snubber network to eliminate parasitic resonances. R3 controls the peak current and the control is exercised in a complex way because of the time varying nature of the excitation inductance. When there is no current in the winding the inductance is extremely high because it is a toroidally wound ring with very high permeability core. This high inductance is maintained until saturation so initially on a transition from the output of U5 the full 5V of the supply appears across the winding. What follows is a gradual increase of current in the inductor which drops more and more voltage across R3. Eventually the current reaches saturation whereupon the inductance disappears and R3 alone limits the current. But this situation lasts for only a short time because the new larger current causes the voltage across C25 to increase which from the point of saturation, it does rapidly. But a while

later,as C25 continues to charge, the voltage across the excitation winding is no longer sufficient to maintain saturation.

The whole process is repeated in reverse when the output of U5 changes state and the voltage across the excitation winding reappears instantaneously as 5V but this time in the opposite direction.

Note that U7 also contains other outputs and in particular on GP1: B_SWITCH. All outputs are generated by in-line code and as the code runs through sequential commands, the operation is mostly "no operation" and occasionally a port bit is changed. The code sequence is written so that the operation of B_SWITCH occurs shortly after the transition of GP5 and is maintained for the duration of the output of the sense winding that is directly caused by the transition into saturation. Different flux gates will have different characteristics and the values of R3 and the code timing will depend on which type of fluxgate the circuit is driving. The same code can be used for AR35 and AR45 types.

Fig. 1 shows two other lines on U7, A_SWITCH and Q_DRIVE. These are used when the flux gate is also used for pitch and roll under Autonic's inclinometer patent. When this is used, GP2 is used as an input which when active disables the output of B switch and activates the output A switch but with exactly the same timing. This is so that the sense circuits can be duplicated to add pan and tilt.

3.2 Sense

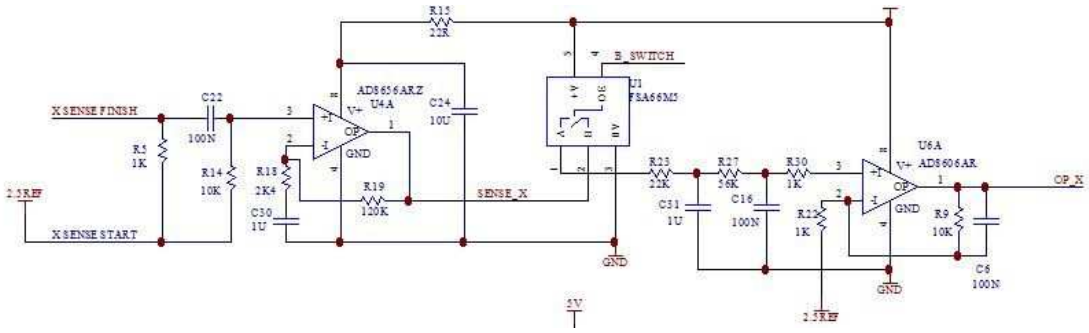

Fig. 2 shows the two stages of the sense analogue circuits. The sense winding is connected between the input of U4A and a low impendence mid rail voltage called 2.5REF. On saturation and de-saturation transitions a voltage will appear on the sense winding if there is a magnetic field present and an important aspect of this output is that it contains no net average value so that it can be connected to the amplifier through a blocking capacitor C22. An advantage is that DC current can be applied to the sense winding so as to create a magnetic field where very sensitive magnetometry is required. In this case the field created by the applied current is generally so as to oppose the ambient field allowing very high amplifier gains so as to enhance the sensitivity of the measurement. Ultimately this sensitivity is limited by signal to noise and it should be noted that the noise level of these circuits described is of the order of 1nT.

U4A is used as a straight forward gain stage with a gain in the region of 50. This value is chosen so that the output of U4A does not reach either 5 volts or 0 volts under the maximum field condition likely to be encountered. Autonic has chosen 50 microT for the A407X and 408X so as to represent the highest value of the earth's magnetic field likely to be encountered anywhere in the world. It should be noted in passing that the A4051 is available with much higher gain for this stage for applications in differential magnetometry or gradiometry.

The amplifier of U4A need not have a low offset but should have good bandwidth.

The remaining half of the sense circuits contains 3 elements, the switch, a filter, and a DC amplifier. The switch, U1, is driven directly from the wave form generator U7 by the signal B_SWITCH and connects the low impendence output of U4A to the passive filter network at the critical time period when the voltage is generated by the core transition of the flux gate. The first part of the filter is a simple averaging circuit of R23 and C31 and the large value of 1 µF. The remaining elements of the filter serve to reduce ripple. U6A is chosen to have an excellently low offset and its purpose is to amplify the averaged signal up to the maximum value possible which is normally maintained between 1 and 4 volts centred at 2.5 volts.

The Y channel is identical and its switch is driven also by B_SWITCH.

The above detailed description is of the circuit in A407X and describes a complete stand alone 2 axis magnetometer with analogue outputs of plus or minus 1.5 volts to represent plus or minus 50 microT.

A point to note is that 2.5 REF is generated simply by the 2 resistors R1 and R2 and is not a particularly low impedance. Therefore the value of R23 should be kept high and we recommend at least 47K . The regulator included on the analogue board is capable of operation up to a maximum input of 15V. The entire circuit of the analogue section is shown is Fig. 4.

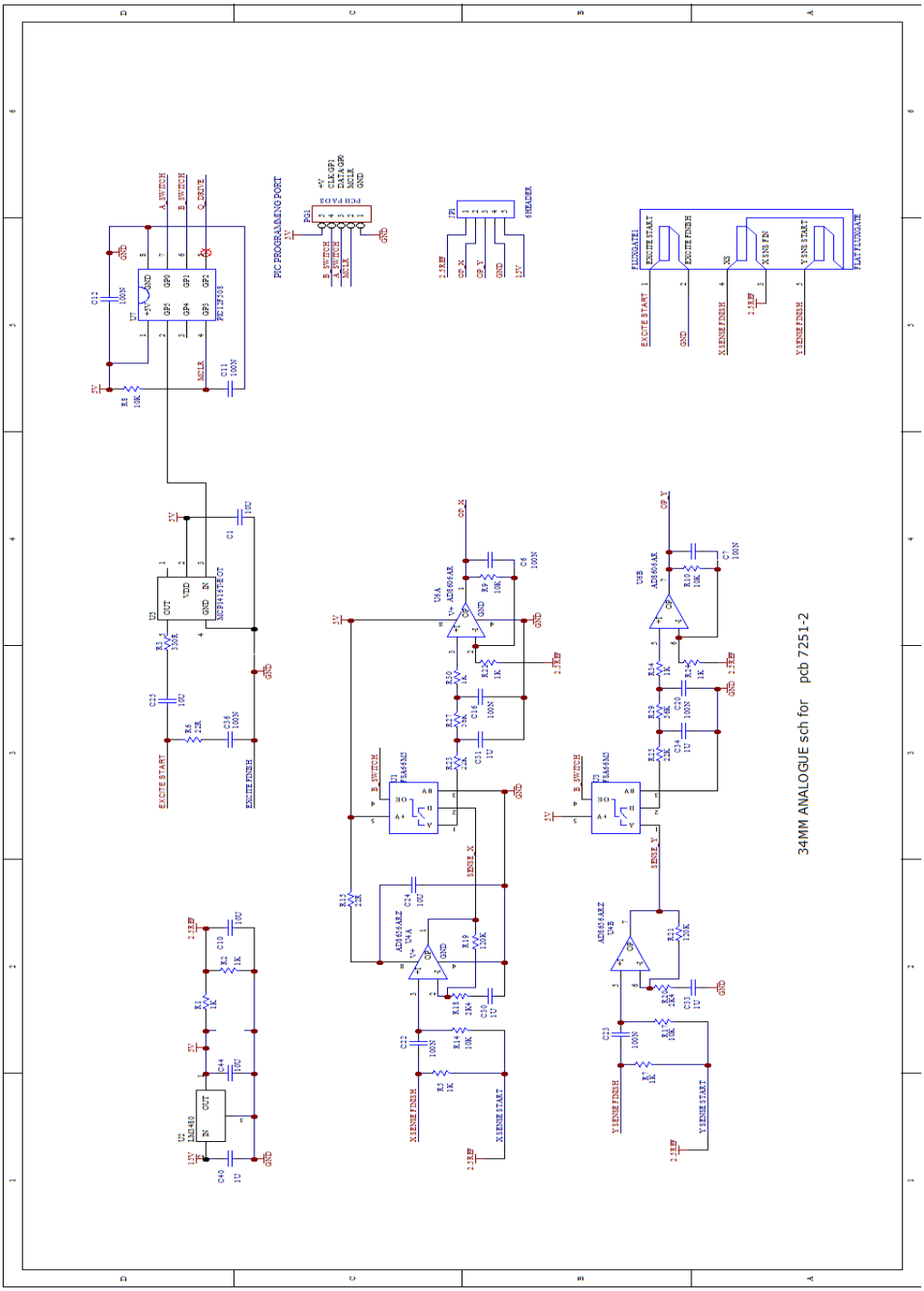

Fig 3

3.3 Digital

The A408X series of magnetometers with digital output contain 2 boards one of which, were it separated, would be designated one of the A407X series; the combined product code for the two boards together is A408X and the digital board is not available on its own.

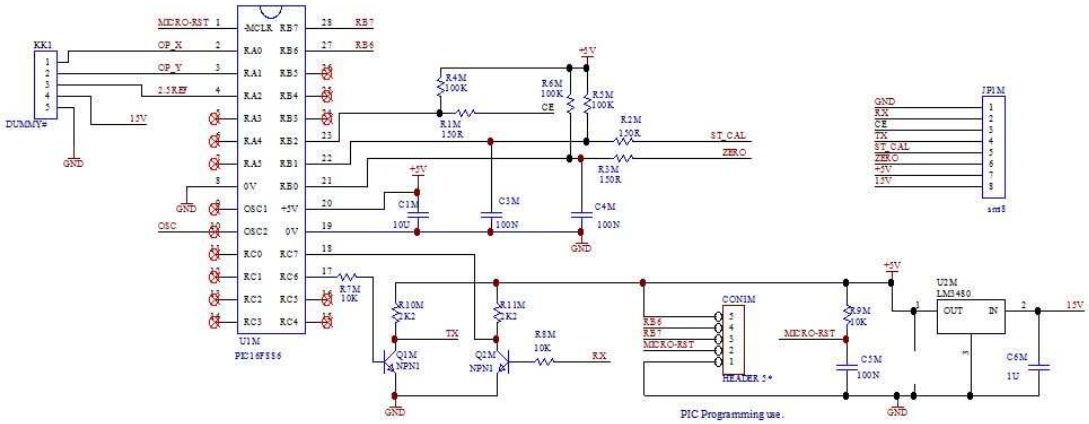

Fig 4

The micro processor, U1M, contains a UART for serial communication which uses the signal lines RC6 and RC7. RA0, RA1, and RA2 are used for analogue inputs and measure not only the output of the X and Y amplifier channels but also the value of the signal called 2.5 REF. This reference, whatever its value,will be the value will be the magnitude of zero magnetic field and this is done because of its simple derivation it is likely to be within only 200mV of the nominal value. By measuring it, it is not important that it is derived in a simple way.

The processor performs the following functions:

A The measurement of X and Y and from each it subtracts the measured reference.

B It then forms the operation of arc tan on these values to derive an angle.

C It communicates using the commanded format on the serial channel.

The data sheet and manual list a set of commands which can be applied to the serial input which regulate the frequency with which the measurements are made, the format of the output string and the initiation of auto-calibration as well as the instant at which the current measured angle is to be set to zero.

The auto-calibration initiation can also be done either by a hardware line to RB1 or by command. Similarly the setting of zero can also be commanded or in hardware by the assertion of a signal to RB0.

The auto-calibration method used is to equate time with angle which means that the vessel to which the compass is attached must be rotating at a constant angular velocity. Once this has been established, the command to start auto-calibration is given and the angular velocity is maintained for around 400 degrees, whereupon the auto-calibration ceases. The end of auto-calibration is given by a serial string as well as the change of state of a hardware line driven by RB2.

End

Doc ref: AN7-1-01

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