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ON THE SUITABILITY OF AUTONNIC FLUXGATES FOR SONARBUOYS

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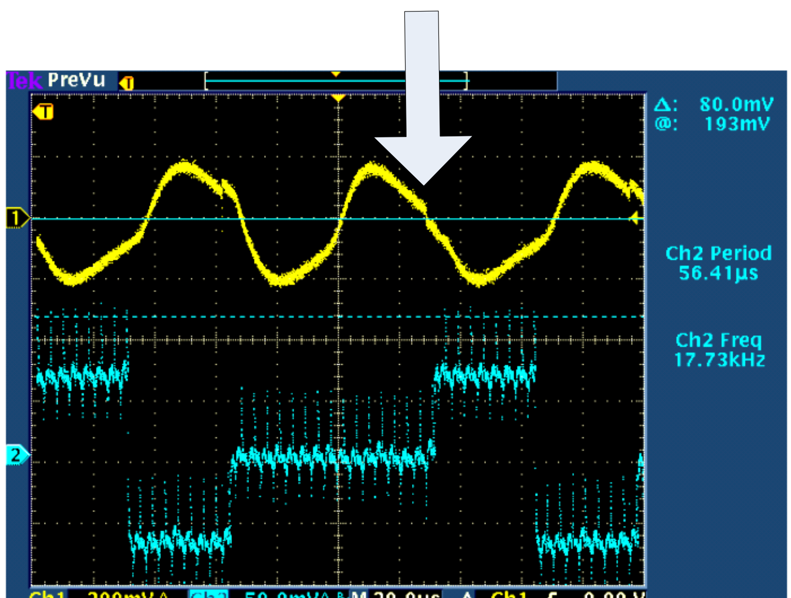
1 Introduction

Sonarbuoys have been used for many years all over the world to listen for submarines. They contain directional microphones systems but the direction has meaning only when it is linked to an indication of the heading. This heading information is derived from a magnetic compass of which the most cost-effective has been and remains the floating-core fluxgate [Ref 1]. It features simple electronics, high sensitivity, low drift and offset together with the ability to eliminate pitch and roll errors from the heading. This last feature is particularly important in portable and marine environments.

2 Classic Sonarbuoy circuits

Sonarbuoys use analogue audio-band modulation techniques which originated many years ago. The investment in reception and analytical equipment installed in aircraft means that compatibility is essential.

The basic output information is in the form of a three-step waveform which also carries both the acoustic analogue signals. Heading data is the phase of the 3-step waveform itself. It is shown in Fig 1.



TOP   Input to modulator. Note hysteresis at zero-crossing (arrow).

BOTTOM Output from modulator showing 3-step wave. The phase of this wave carries the heading information and is synchronised to the negative zero-crossing of the TOP waveform. Heading is the phase of this waveform relative to a 15kHz reference.

FIG 1

In Fig 1 the bottom trace moves from left to right with heading. The arrow shows the zero-crossing which triggers the start of the

High , low, middle, middle

which we refer to as the 3-step waveform.

3 Heading signals

Fluxgate operation is described in basic form in Autonnic Application Note 2 [Ref 1] and details of circuits in our Application Note 3 [Ref 2]. These describe the fundamental operation of the sensor which involves the change of state of the magnetic material in the fluxgate core. The notes show the essential need for two distinct circuits:

excitation drive and
output amplification.

3.1 Drive

Within the Sonarbuoy electronics there are very few components which deal with the compass. These are shown in Fig 2. The modulator circuit produces a crystal-controlled square-wave at approximately 7.5kHz which is connected to a emitter-follower pair of transistors to form the excitation drive. The drive signal at TP17 is from an integrated circuit the supply to which is regulated so that the drive is also regulated against supply voltage variations and is about 6v peak to peak. The supply is typically from a 12v lead-acid battery.

3.2 Output (sense) amplification

The output signals are handled in an entirely different way from that which would be found in a modern fluxgate compass. The X and Y output signals are added together with a phase-change on one axis (components C43, R85 and R84) so as to produce an output at twice the excitation frequency and in which the heading is contained in the phase of the 15kHz (in this case being 2 x 7.5kHz) output relative to one edge of the excitation drive.

4 The compatibility challenge

Fluxgate are essentially the same but differ in the magnitude of their characteristics. These characteristics are in turn are governed by:

- the metal of the core,
- the diameter of the core and
- the winding details.

In Fig 2 the components labelled 'NEW' must be changed if the fluxgate is changed.

NOTE: In normal fluxgate applications the occurrences of saturation and de-saturation are carefully managed by micro-controller and the output pulses are collected by carefully timed switches.

Because of the 15kHz output required in this application the most important design demand is that the output pulses must be evenly spaced. However, the basic nature of a fluxgate is such that the output is entirely dependant on the input and therefore the input excitation drive must deliver saturation and de-saturation at equal intervals.

In all compass applications the direction information is not dependant on amplitude but the ratio of the X amplitude and the Y amplitude. Note also that both X and Y occur at the same time.

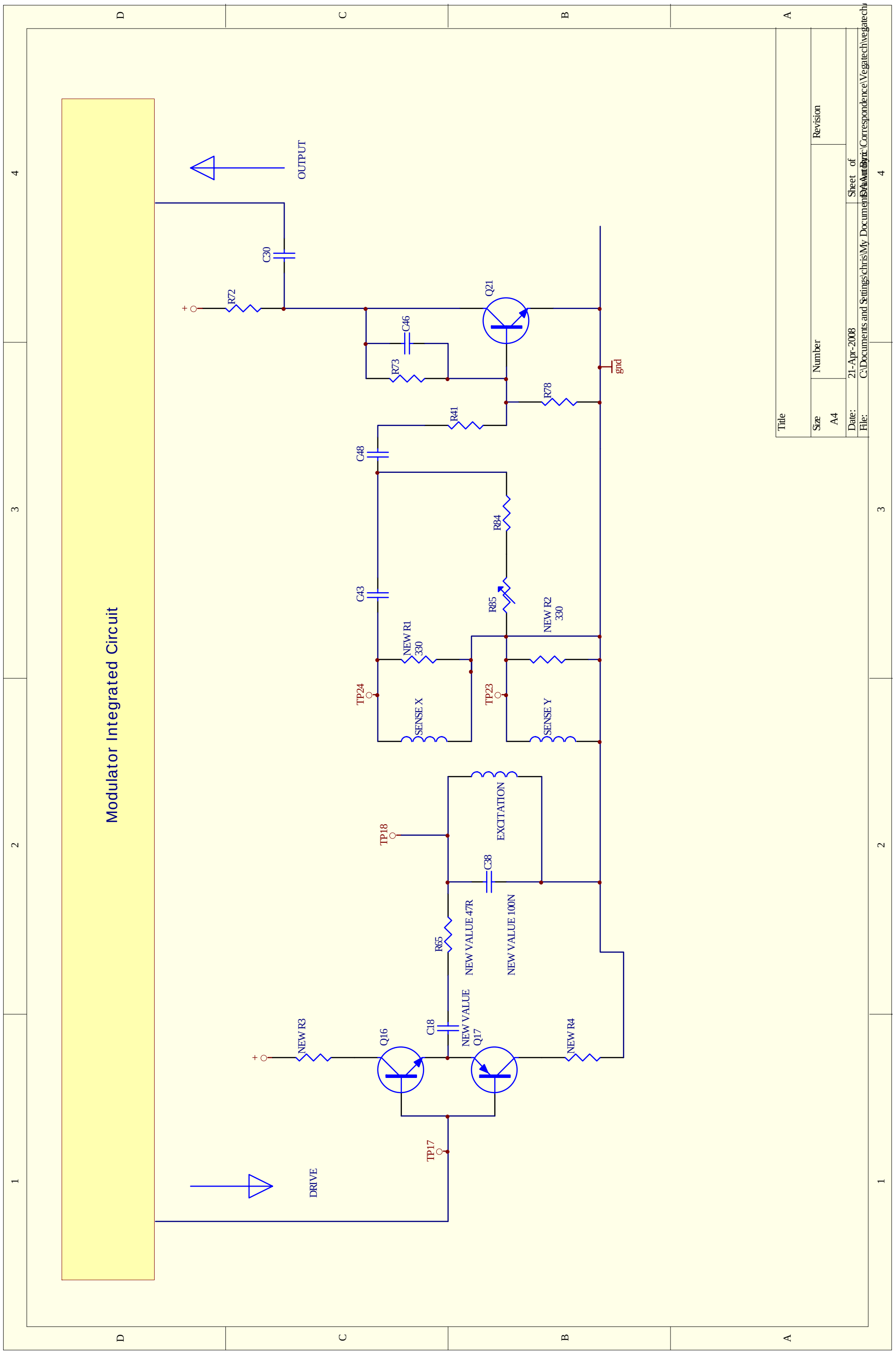

Modulator Integrated Circuit
OUTPUT
DRIVE
R72
C30
C46
R73
Q21
gnd
R78
R41
C48
R84
C43
R85
NEW R2
330
NEW R1
330
TP24
TP23
SENSE X
SENSE Y
EXCITATION
TP18
C38
R65
NEW VALUE 47R
NEW VALUE 100N
C18
NEW VALUE
Q17
Q16
NEW R3
NEW R4
TP17
Title
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FIG 2

4.1 Arranging equal timing

The 7.5kHz drive has a duration of approximately 132µs and within this period 4 output pulse events must occur and therefore the period between saturating and unsaturating events is 33µs

To achieve this is a difficult process of analysing which component in the drive path affects saturation in any particular fluxgate. The details of waveforms of current and voltage on the excitation winding will be different for every fluxgate and some time must be spent in noting how the change of the drive components affects the timing. Broadly the components have the following influence:

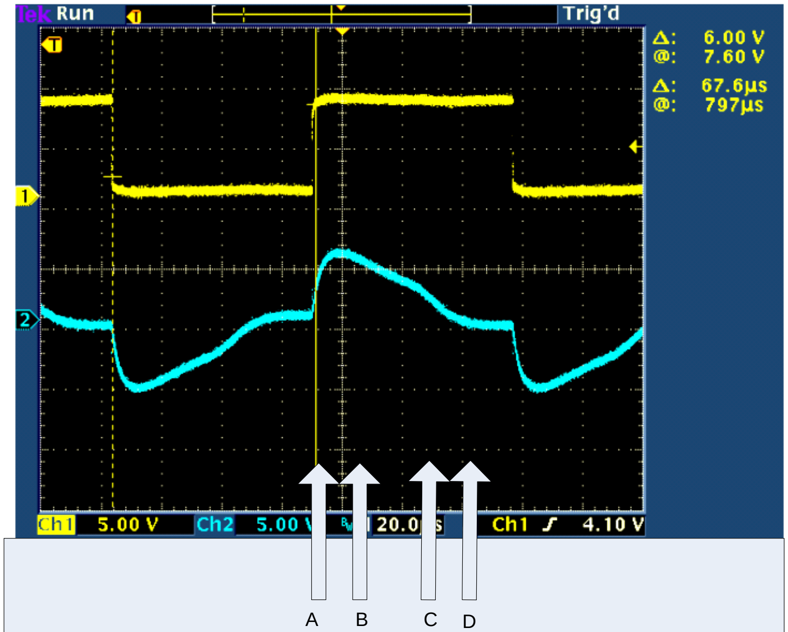
4.2 Component details

C38 is important as in combination with R65 it limits the rate of rise of voltage on the excitation winding. The fluxgate can only withstand so many volt-seconds before the core saturates and for a Sonarbuoy the excitation frequency is fixed and therefore a good place for saturation to occur is in the region of 40µs after the rising edge. Fig 3 shows this in detail.

R65 must be such that the core saturation is reached but not too greatly exceeded otherwise C18 will be discharged too rapidly. For the AR35 range a suitable value is 47R.

The un-saturating events are not visible on the voltage waveform but occur very soon after the 7.5kHz drive switches. The core rests saturated with the current maintained by R65 and C18 until driven rapidly out of saturation by the application of volts in the other direction. As soon as the core state changes the winding resumes a large inductance and block current.

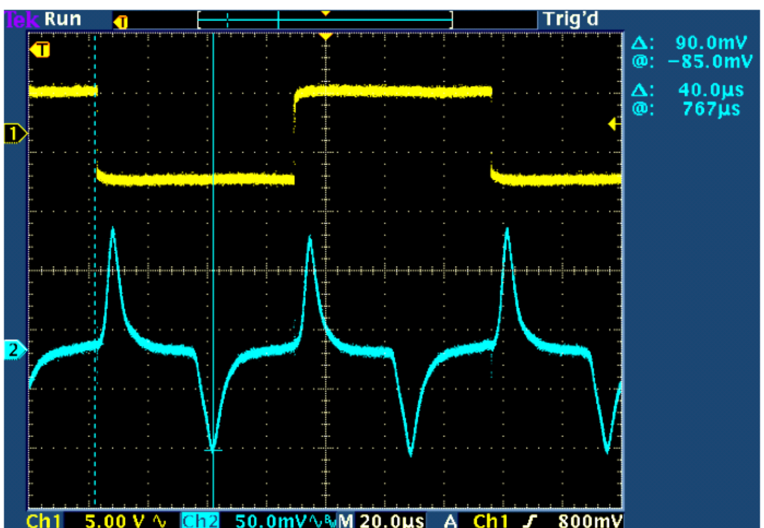
In Fig 3 the de-saturation event is about 5µs after the rise or fall of the drive signal (TP17).



Main excitation events

A Voltage is applied with R65/C38 rise-time
B Full voltage reached and current rises in the excitation winding inductance until at
C the core saturates and the inductance falls.
D all volts are dropped across R65 and if left for a long time C18 would discharge as well

Fig 3



TOP Drive reference
BOTTOM Sense winding output (only one winding shown)

Fig 4

The timing is confirmed by the output pulses shown in Fig 4 which shows the pulses from one of the sense windings. In this particular case the output pulse is negative for a saturating event and positive for a de-saturating event. If the fluxgate were in another azimuth these could be reversed - or if aligned at 90° to the field the output pulses could all be zero and not visible. In the figures shown the sense winding is at maximum output.

Referring to Figs 2 and 4, the width of the output pulse can be extended by loading them. 330R is a good load for the AR35S and results and the almost sinusoidal final output of Fig 1.

In summary for the AR35 (S or D):

C18	330nF
R65	47R
C38	100nF
NEW R1	330R
NEW R2	330R
NEW R3	-
NEW R4	-

The low value of R65 might mean that the dissipation in Q16 and Q17 is considered too high. Adding the NEW resistors R3 and R4 in the collectors spreads the heat.

5 Other considerations

When dealing with fluxgates some care must be taken to ensure consistent drive. The amplitude output pulse from the sense windings is itself not important as it the ratio of the X and Y outputs which contains the heading information. But in the Sonarbuoy circuits the even timing is also important as the ratio is simply obtained by phase shift summation. Therefore care must be taken that input drive components do not affect timing. The Sonarbuoy circuits should contain a regulator and the capacitors and resistors must have a good temperature coefficient.

The output phase-shift components and the output amplifier need no change as they will already have been optimised for a 15kHz 'sine' wave.

6 Conclusions

The Sonarbuoy 7.5/15kHz phase indication circuits are a relic of a pre-microcontroller era. Nevertheless the circuits can be adapted to suit an Autonnic fluxgate such as the AR35S which is well within the power of the drive circuit. By careful selection of components the core event times can be exactly evenly spaced and give excellent results.

7 References

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1 Autonnic Application Note AN-2 WHAT IS A FLUXGATE MAGNETOMETER

2 Autonnic Application Note AN-3 EXCITATION AND SENSE METHODS FOR RING FLUXGATE MAGNETOMETERS

3 Autonnic Data Sheet AR35XX

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