SA5775 Air core meter driver applications information — AN1761

INTRODUCTION

The SA5775 is a monolithic Serial Gauge Driver (SGD) which can be used to directly drive Air Core Meters (ACM), typically used in automobile dashboards (Figure 1). The circuit interfaces with the serial bus of a microprocessor, has 10-bit resolution (0.35 degrees) and is guaranteed to be monotonic. Data can be shifted through the part so that several SA5775s can be cascaded with only one chip select line. On-board circuitry protects the circuit from external faults.

PRINCIPLES OF AIR CORE METERS

In many meter applications hitherto, D'Arsonval type of movements have been used. In this, a field coil is used along with a permanent magnet. When a current passes through the field coil, it generates a magnetic field. The magnetic field, due to the field coil, interacts with that due to the permanent magnet producing a resultant force that causes a needle to deflect, the deflection being controlled by a spring. Calibration of the current results in known deflections of the needle which is used to indicate the desired reading. While the advantage of such a system lies in its low cost and well-known behavior, there are also a number of disadvantages.

1. The strength of the mechanical spring degrades with age and with temperature cycling.
2. The permanent magnet ages with a lessening of the magnetic field. This makes it harder for it to pull the needle against the spring.
3. The mechanism is prone to damage due to vibrations from handling and other causes.

To overcome some of these problems, Air Core Meters have been used quite successfully. In this type of movement, there are two coils which are wound at 90° from one another (see Figures 2 and 3). A needle is attached to a magnetized disk that is positioned between the two coils. When currents 90° out-of-phase with each other pass through the two coils, the resultant magnetic fields produce a force which moves the disk. The position of the disk is dependent upon the ratio of the currents in the two coils. By varying this ratio, the disk and hence the needle position can be varied.

The advantage of such a type of movement lies in the fact that:

1. There are no springs
2. Only effect of magnetic strength degradation with age is in slowing of mechanical response time
3. Accuracy does not degrade with age
4. Not prone to damage due to vibration/handling on account of rugged sleeve bearings
5. Built-in damping

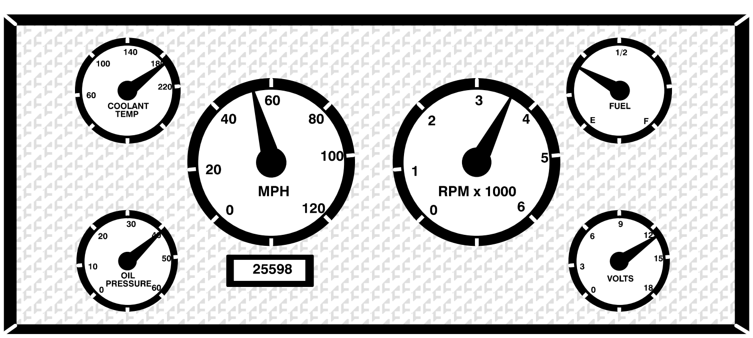
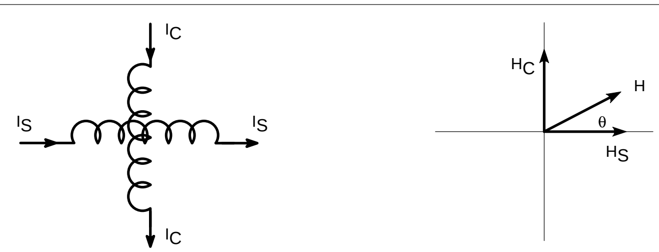


Figure 1. Analog Instrument Cluster



(a) (b)

Figure 2.

THEORY OF OPERATION

In a solenoid, the strength of the magnetic field produced is given by

$$H = nI$$

where n = number of turns
I = current through the coil

When two coils are placed at right angles as shown in Figure 3 with the currents through the two coils being I_C and I_S, the resultant magnetic fields are

$$H_C = n\, I_C \quad (1a)$$

$$H_S = n\, I_S \quad (1b)$$

Then the magnitude of the resultant magentic field H is given by the vector sum of H_C and H_S, namely

$$|H| = \sqrt{H_C^{\,2} + H_S^{\,2}} \quad (2)$$

and the angle of the magnetic field is

$$\angle H = Arc\ \tan\left(\frac{H_S}{H_C}\right) \quad (3)$$

The currents I_C and I_S have the form and relationship as shown in Figure 4, so that

$$I_C = I\ Cos\left(\frac{360^o}{1024}\ Code\right) \quad (4a)$$

$$I_S = I\ Sin\left(\frac{360^o}{1024}\ Code\right) \quad (4b)$$

as 2^{10} bits are used for resolution of 360° and where code is the input code.

Substituting 4a and 4b in (1), (2) and (3) yields

$$|H| = n\ I \quad (5)$$

and

$$\angle H = Arc\ \tan\left(\frac{Sin\ \theta}{Cos\ \theta}\right) = \theta$$

where

$$\theta = \left(\frac{360^o}{1024}\ Code\right) \quad (6)$$

From Equations (5) and (6), it is clear that the torque which is dependent upon |H| is a constant if I is constant and θ is linearly dependent upon the input code.

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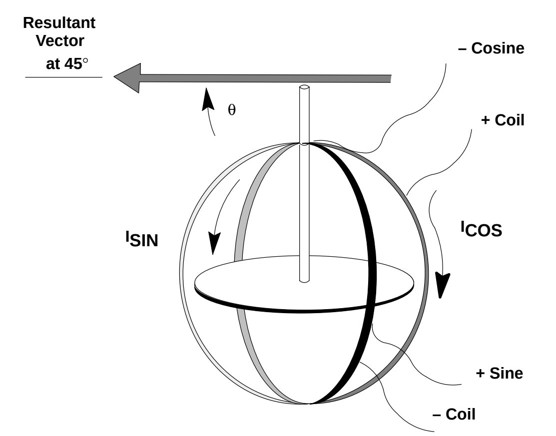

Figure 3.

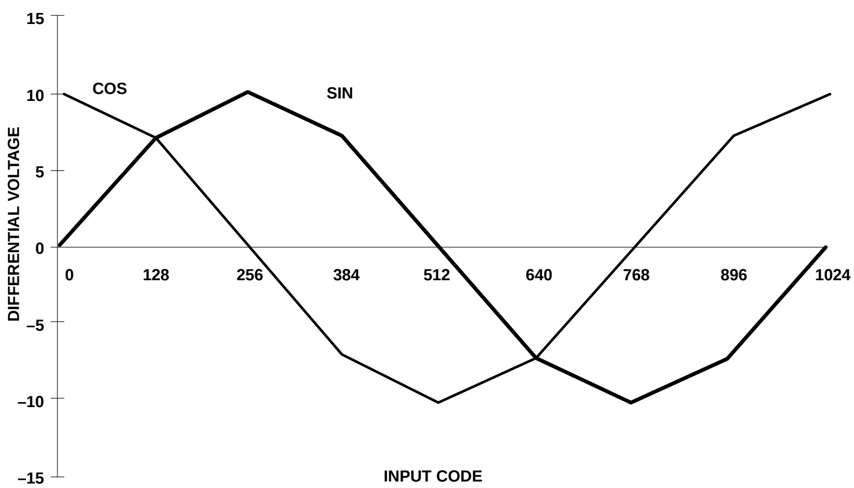

Figure 4. SA5775 Output Voltages (V_{IGN} = 14V)

In actuality, a voltage V is used to drive the coils so that

$$I = \frac{V}{R} \tag{7}$$

where R is the resistance of the coil and in this case, it is assumed that both coils have the same resistance. Thus

$$|H| = \frac{n\ V}{R} \tag{8}$$

Voltage drive has advantages over current drive since there is

1. No back EMF problem
2. No headroom problem
3. Better precision
4. Ratiometric drive

BLOCK DIAGRAM DESCRIPTION

The logic block contains the 10-bit input shift register and a 10-bit parallel latch for the DAC. The DAC generates two output voltages that are offset within the supply rails to give the output buffers enough headroom to operate. With a 14V supply, the typical output swing is from 1V to 11V. V1 and V2 are the DAC outputs that provide the relationnship between the SIN coil voltage and COS coil voltage to create the desired display pointer deflection. The MUX generates all four quadrants by switching the

90 degree data from the DAC to the appropriate output buffer. The output buffers provide the necessary current to drive the air core gauge. The output buffers are always connected to the coils and can sink and source sufficient current so that inductive kickback is eliminated during normal operation.

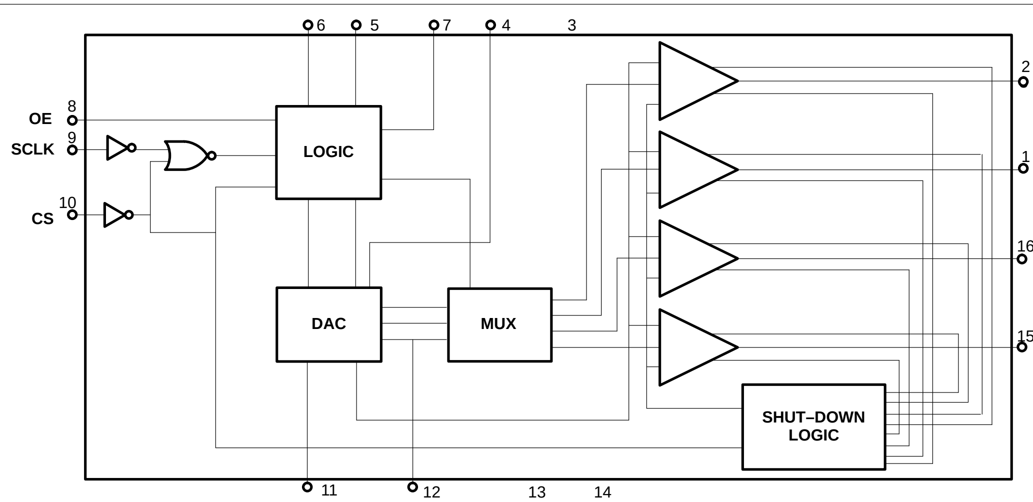

Figure 5. SA5775 Block Diagram

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The primary function of the SGD IC is to generate the transfer function that maps an input code into the correct voltages for linearly controlling the SIN and COS coils of an air core display. This circuit receives commands via an internal serial data interface port which is SPI compatible. The parts can be serially cascaded to minimize the necessary interface signals in multi-chip systems. The SGD has 10-bit resolution (0.35 degrees) and is guaranteed to be monotonic. The input data is directly proportional to the displayed angle in degrees. An input code of all 0's gives an output angle of 0.176 degrees; all 1's will generate a full-scale output of 359.82 degrees (see Table 2). The SGD output buffers are capable of sourcing up to 80mA per differential driver to control a single air core display directly.

FUNCTIONAL DESCRIPTION

The SA5775 which is housed in a 16-Pin package has terminal connections as shown in Figure 6. The function of each pin is described in Table 1.

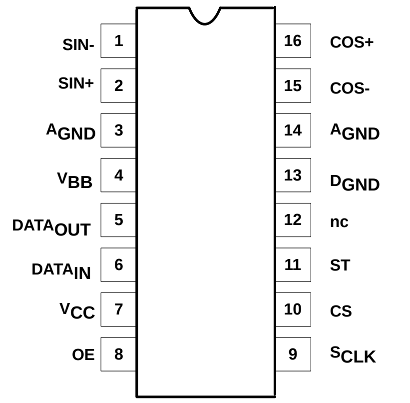

Figure 6. Pin Configuration

Table 1. SA5775 Pin Descriptions

Pin #	Name	Function
1	SIN–	Negative output connection to the SIN coil of the gauge.
2	SIN+	Positive output connection to the SIN coil of the gauge.
3	A_{GND}	Ground for V_{IGN} supply. Pins 3, 13 and 14 connected on the ckt board.
4	V_{BB}	Analog supply. Nominally 14.0V.
5	$DATA_{OUT}$	Serial data output. Output of the internal shift register. When a new data word is shifted in, the old word is shifted out the $DATA_{OUT}$ pin.
6	$DATA_{IN}$	Serial data input. A new data word is serially shifted into the part on the rising edge of S_{CLK}. The data is shifted in MSB first.
7	V_{CC}	5V logic supply. The internal latches and registers are set to zero on the rising edge of this signal.
8	OE	Output drivers are turned off when this input is low. Current draw is minimized.
9	S_{CLK}	Serial clock input. Data is loaded into the part on the rising edge of S_{CLK}.
10	CS	Active high chip select input. When CS is high, the part is enabled to receive a new serial input word. The high-to-low transition of CS loads the new 10-bit word into the DAC registers and updates the output.
11	ST	Status output from this IC to indicate that the outputs have been disabled. The outputs may be disabled due to shorted outputs, over temperature conditions, power up reset, or output enable control pin. This output is an open drain output. Multiple status outputs may be wire OR'ed together. This output is low when the outputs are disabled due to a fault condition.
12	nc	Not connected
13	D_{GND}	Ground for V_{CC} supply. Connect to Pins 3 and 14.
14	A_{GND}	Ground for V_{BB} supply. Connect to Pins 3 and 13.
15	COS–	Negative output connection to the COS coil of the gauge.
16	COS+	Positive output connection to the COS coil of the gauge.

Table 2.

Ideal	Nominal	Input Code
0	0.176	0
45	45.176	128
90	90.176	256
135	135.176	384
180	180.176	512
225	225.176	640
270	270.176	768
360	359.820	1023
N = Binary Input Code		
Equation for Output Angle (θ) vs Output Voltage		
Quadrant	**Equation**	
I	$\theta = \tan^{-1} \mid [(SIN+) - (SIN-)] / [(COS+) - (COS-)] \mid$	
II	$\theta = 180° - \tan^{-1} \mid [(SIN+) - (SIN-)] / [(COS+) - (COS-)] \mid$	
III	$\theta = 180° - \tan^{-1} \mid [(SIN+) - (SIN-)] / [(COS+) - (COS-)] \mid$	
IV	$\theta = 360° - \tan^{-1} \mid [(SIN+) - (SIN-)] / [(COS+) - (COS-)] \mid$	

SERIAL INTERFACE

The SGD is controlled through a serial interface with the following control functions:

S_{CLK}

Serial input clock. When CS is high, the rising edge of S_{CLK} shifts a new data bit into the SGD.

CS

Active high chip select. Enables the SGD to receive serial input data. The falling edge of CS loads a new 10-bit data word into the internal DAC register which updates the output.

DI

Serial data input. The data at this pin is shifted into the internal shift register on the rising edge of S_{CLK}. Data is shifted in MSB first.

DO

Serial data output. This pin is the output of the internal shift register. The data output on this pin is the input data from DI pin delayed by 11 clock cycles. This pin can be used to cascade several SGDs with one CS line to load all of the SGDs concurrently.

Power Moding

This device has a power on reset. On the rising edge of V_{CC} the internal latches and registers are set to zero and the outputs are disabled.

Output Driver Control

Directed control of the outputs can happen in one of several ways:

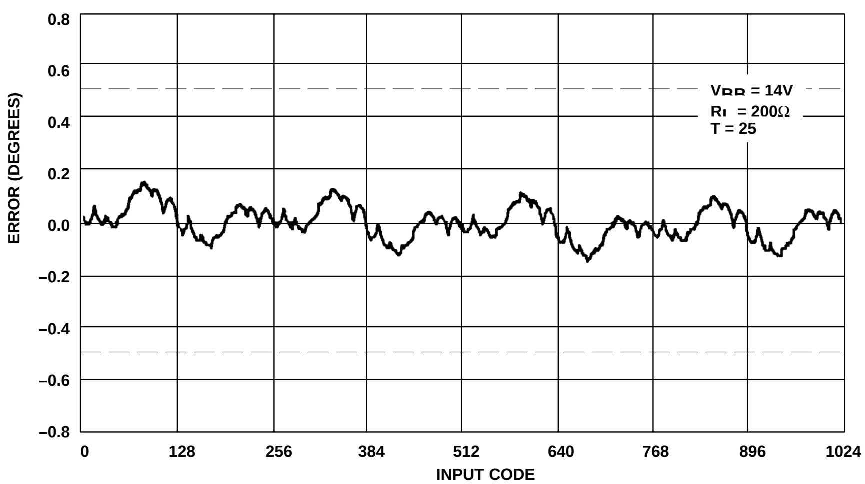

Figure 7. Error Graph

1. The outputs are disabled with the rising edge of V_{CC}.
2. The outputs are disabled when OE is taken low or held low. The data registers for the outputs can still be updated while OE is low. When OE is taken high, the current output data value is displayed. A falling edge on CS will be required to activate outputs if a fault condition has occurred prior to the OE going high.
3. The outputs are disabled if an overcurrent condition exists on either of the coil output buffers. The coil output buffers will be enabled after the next CS high-to-low transition; assuming OE is high. If the overcurrent condition has not been removed, the outputs will immediately return to their disabled condition. The ST pin will indicate status of the coil outputs.
4. The outputs will be disabled by thermal shut-down circuitry if there is excessive power dissipation. The die temperature must go below 140°C before a falling edge on the CS pin will clear this fault condition and allow the coil outputs to go active.

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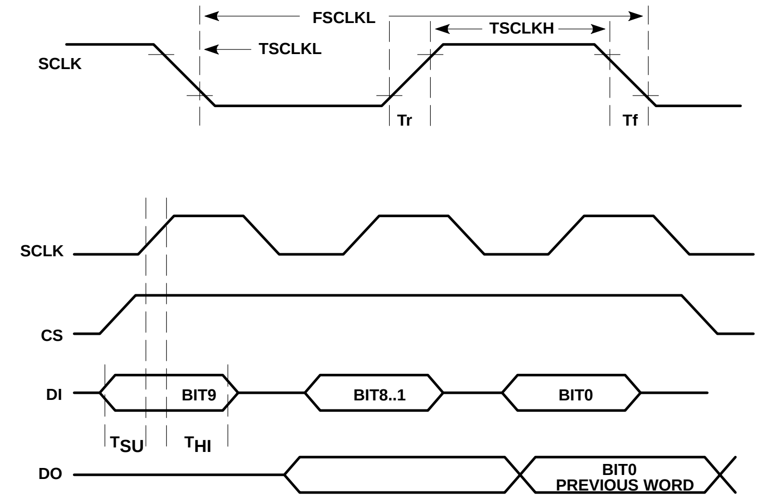

Figure 8. Serial Interface Timing