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# DATA SHEET

**SA5778**

Serial triple gauge driver (STGD)

Product specification  
Supersedes data of 1997 May 27  
IC18 Data Handbook

1998 Apr 03

# Serial triple gauge driver (STGD)

SA5778

## DESCRIPTION

The Serial Triple Gauge Driver (STGD), is a single chip air core driver providing drive to one major gauge, and two minor gauges, for automotive applications such as Speedometer, Fuel, Temperature, Tachometer, Volts, and Oil pressure information display. The STGD operates in conjunction with a microcontroller receiving serial data inputs, and can provide status back to the microcontroller either serially or via a status line. The protocol is compatible with the Philips Single Gauge Driver (SGD) and Dual Gauge Driver (DGD). The STGD also includes a protected battery supply for external single Serial Gauge Drivers or Dual Gauge Drivers.

## PIN CONFIGURATION

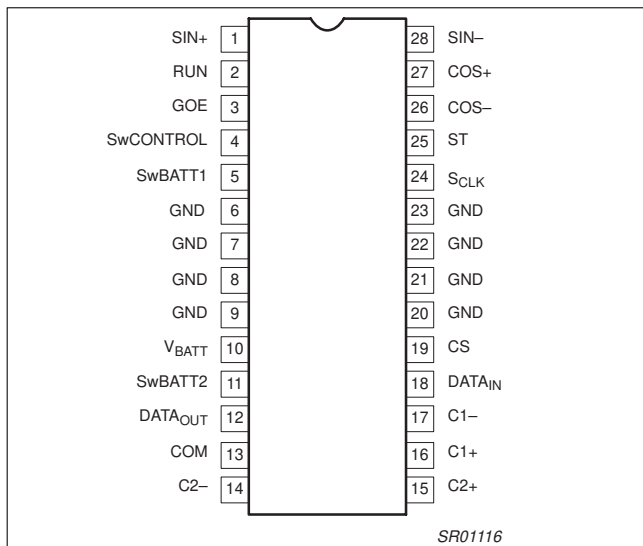


Figure 1. Pin Configuration

## FEATURES

- Major Gauge 10-bit resolution Drive provides 0.35° resolution
  - Sine/Cosine outputs for 360° operation
  - 0.2° accuracy typical throughout entire range
- Minor gauge drivers provide 0.35° resolution
  - 112° operation
  - 0.5° accuracy typical throughout entire range
- Serial Data Input
  - Supports interface from microcontrollers
  - Compatible with Philips SGD SA5775A and DGD SA5777A
- Serial Data Output
  - Permits the STGD to be wired in series using a common chip select to additional STGDs, SGDs, and DGDs
  - Permits fault status information to be returned to the microcontroller
- Over Voltage Protection, Over Temperature Protection and Low Standby Current Operation
  - Gauge drivers disabled when supply voltage exceeds specified operating voltage, protection to 40V.
  - Gauge drivers disabled when die temperature exceeds operating range
  - External switch may supply overvoltage protected battery supply to other devices operating off battery
- Thermally Enhanced SO-28 surface mount package

## BLOCK DIAGRAM

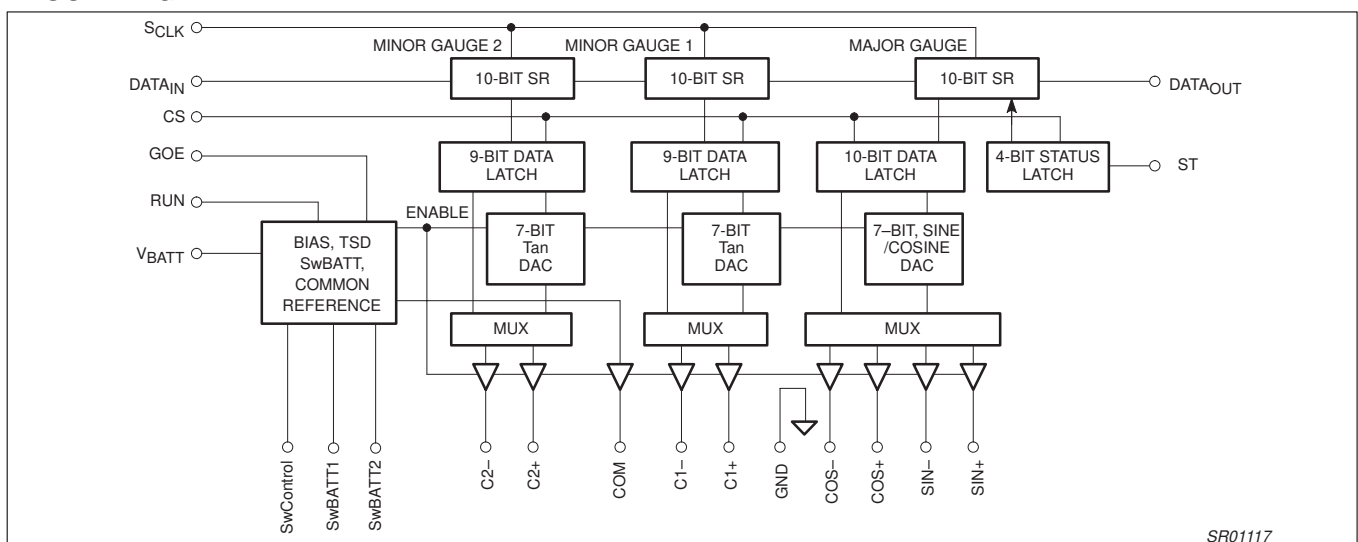


Figure 2. STGD Internal Block Diagram



## Serial triple gauge driver (STGD)

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## ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
28-Pin Small Outline (SO) thermally enhanced Package	-40 to +105°C	SA5778D	SOT136-1

## PIN DESCRIPTION

Mnemonic	Pin No.	Type	Name and Function
GND	6,7,8,9,20,21,22,&23	I	<b>Circuit Ground Potential.</b> The pins are used for heat dissipation to board. All pins should be soldered to foil on the board per the thermal management description.
V <sub>BATT</sub>	10	I	<b>Battery supply voltage</b>
GOE	3	I	<b>Gauge Output Enable:</b> A high on this input enables normal operation of the gauge coil drivers. See Table 1.
RUN	2	I	<b>RUN (Ignition):</b> Input to sense the state of the Ignition switch. See Table 1.
SwCONTROL	4	O	<b>Switched Battery Control:</b> Control output to switch on a protected V <sub>BATT</sub> supply via an external PNP transistor. This output is controlled by the RUN input, GOE input and the on chip protection circuits.
SwBATT1 SwBATT2	5, 11	I I	<b>Switched Battery Supplies:</b> Used as the reference level for the DACs, bias voltage for the second coils of the minor gauges, and the supply for the output buffers for the major and minor gauges. One supplies the major gauge drivers and related circuits, while the other supplies the minor gauge circuits. Both SwBATT inputs must be connected to the control transistor as the two inputs are not connected internally.
S <sub>CLK</sub>	24	I	<b>Serial Clock:</b> Used to clock data into and out of the STGD. Data is shifted MSB first.
DATA <sub>IN</sub>	18	I	<b>Data In:</b> Data is loaded on the rising edge of S <sub>CLK</sub> and is shifted in MSB first.
DATA <sub>OUT</sub>	12	O	<b>Data Out:</b> Is provided to permit the STGD to pass status information back to the controlling microcontroller, and to allow multiple devices to be connected in series.
ST	25	O	<b>Status Output:</b> This is an open drain output. Status outputs from several devices may be wire OR'ed together. This output is low when the outputs are disabled due to a fault condition. The outputs may be disabled due to shorted outputs, over temperature, power up reset, or the GOE control pin and this condition is reflected on the ST pin. The outputs will also be disabled due to an over voltage condition, however this is not reported on the ST pin as over voltage should be a transient condition.
CS	19	I	<b>Chip Select:</b> Active high chip select input. When CS is high, the part is enabled to receive data on the DATA <sub>in</sub> pin and output data on the DATA <sub>out</sub> pin. A low to high transition of CS captures device status in the shift register for output. A high to low transition of CS loads gauge data from the shift register into the data latches.
SIN+	1	O	<b>Sine Positive:</b> Driver output to sine coil of major gauge, positive side.
SIN-	28	O	<b>Sine Negative:</b> Driver output to sine coil of major gauge, negative side.
COS+	27	O	<b>Cosine Positive:</b> Driver output to cosine coil of major gauge, positive side.
COS-	26	O	<b>Cosine Negative:</b> Driver output to cosine coil of major gauge, negative side.
C1+	16	O	<b>Coil 1 Positive:</b> Driver output to driven coil of minor gauge 1, positive side.
C1-	17	O	<b>Coil 1 Negative:</b> Driver output to driven coil of minor gauge 1, negative side.
C2+	15	O	<b>Coil 2 Positive:</b> Driver output to driven coil of minor gauge 2, positive side.
C2-	14	O	<b>Coil 2 Negative:</b> Driver output to driven coil of minor gauge 2, negative side.
COM	13	O	<b>Common:</b> Driver output for junction of bias coils for minor gauges. This output is regulated to half of SwBATT.

## ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNIT
V <sub>BATT</sub>	Battery supply voltage, with recommended 1KΩ series resistor	40	V
V <sub>IN1</sub>	Input voltage; Data In, CS, SCLK, GOE	-1 to +7	V
V <sub>IN2</sub>	Input voltage; Sw <sub>BATT</sub>	-1 to +24	V
V <sub>IN3</sub>	Input voltage; RUN, with recommended RC Circuit	-1 to +40	V
P <sub>D</sub>	Power Dissipation (T <sub>amb</sub> = 105°C) SO-28 Package	1400	mw
T <sub>amb</sub>	Ambient operating temperature	-40 to +105	°C
T <sub>J</sub>	Junction temperature <sup>1</sup>	+150/+160	°C
θ <sub>JA</sub>	Thermal Impedance	See Thermal Management Section	°C/W

## NOTE:

- 160°C junction temperature is permitted during high battery (>16V) fault operation

## Serial triple gauge driver (STGD)

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**DC ELECTRICAL CHARACTERISTICS** $V_{BATT} = 8.0$  to  $16V$ ;  $T_{amb} = -40$  to  $+105^{\circ}C$ 

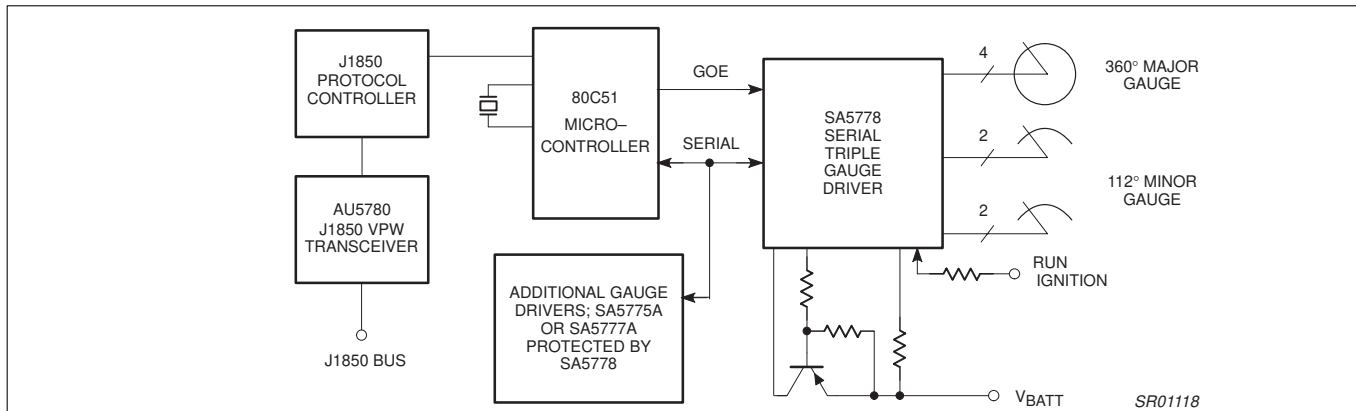
SYMBOL	PARAMETER	TEST CONDITION	LIMITS			UNITS
			MIN	TYP	MAX	
$V_{BATT}$	Battery supply voltage	Normal operating range	8		16	V
$V_{SWBATT}$	Switched battery supply voltage	Normal operating range	7.5		16	V
$I_{BATT}$	Battery supply current, operating	$V_{BATT} = V_{BATTMAX}$ $R_L = R_{LMIN}$			0.5	ma
$I_{SWBATT}$	Switched battery supply current, operating	Normal operating range			400	ma
$I_{BATTSB}$	Battery supply current, standby	$V_{BATT} = 12$ V			60	$\mu$ A
$V_{OH1}$	Output high voltage	DATAOUT, $I_{OH} = 300\mu$ A	4.0			V
$V_{OH2}$	Output high voltage	SwCONTROL, $I_{OH} = 10\mu$ A	40			V
$I_{OH}$	Off state output current	ST, $V_{OH} = 5$ V			25	$\mu$ A
$V_{OL1}$	Output low voltage	ST, DATAOUT, $I_{OL} = 1.5$ mA			0.4	V
$V_{OL2}$	Output low voltage	SwCONTROL, $I_{OL} = 50$ mA @ $V_{BATTMAX}$ $I_{OL} = 20$ mA @ $V_{BATTMIN}$			1.5	V
					1.2	V
$V_{IH}$	Input high voltage	CS, SCLK, DATAIN, GOE, RUN	3.5			V
$V_{IL}$	Input low voltage	CS, SCLK, DATAIN, GOE, RUN			1.5	V
$V_{OVSD}$	Battery overvoltage shutdown voltage	$V_{BATT}$	18		23	V
$I_{IH}$	Input high current	CS, SCLK, DATAIN, RUN GOE; $V_{IH} = 3.5$			10	$\mu$ A
$I_{IL}$	Input low current	CS, SCLK, DATAIN, RUN GOE; $V_{IL} = 1.5$			10	$\mu$ A
ACC1	Output function accuracy, major gauge	$R_L = R_{LMIN}$ ; major gauge, G1	-0.5		+0.5	Deg
ACC2,3	Output function accuracy, minor gauges	$R_L = R_{LMIN}$ ; minor gauges, G2 & G3	-1.0		+1.0	Deg
$V_{DRIVE1}$	Coil drive voltage, major gauge		68	71	78	% $SW_{BATT}$
$V_{DRIVE2,3}$	Coil drive voltage, minor gauges		70	74	80	% $SW_{BATT}$
$R_{LMIN}$	Minimum coil load resistance	$T_{amb} = 105^{\circ}C$ $T_{amb} = 25^{\circ}C$ $T_{amb} = -40^{\circ}C$	226			$\Omega$
			171			$\Omega$
			127			$\Omega$
$V_{COM}$	Minor gauge bias voltage	$I_{OB}$ (Source or Sink) $R_L = R_{LMIN}$	$0.475 \times$ $SW_{BATT}$		$0.525 \times$ $SW_{BATT}$	V

**AC ELECTRICAL CHARACTERISTICS** $V_{BATT} = 7.5$  to  $16V$ ;  $T_{amb} = -40$  to  $+105^{\circ}C$ 

SYMBOL	PARAMETER	TEST CONDITION	LIMITS			UNITS
			MIN	TYP	MAX	
$t_{CYC}$	Clock cycle time		625			ns
$F_{SCLK}$	Clock frequency	$T_{CYC}$			1.60	MHz
$t_{SCLKL}$	SCLK LOW time		175			ns
$t_{SCLKH}$	SCLK HIGH time		175			ns
$t_{CSH}$	CS high to SCLK high time		75			ns
$t_{CSL}$	SCLK low to CS low time		75			ns
$t_{SU}$	DATAIN setup to SCLK high time		75			ns
$t_{HD}$	SCLK high to DATAIN hold time		75			ns
$t_{DR}$	DATAOUT rise time	0.8 to 3.6V; $C_L = 90$ pF			75	ns
$t_{DF}$	DATAOUT fall time	3.6 to 0.8V; $C_L = 90$ pF			75	ns

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**Figure 3. System Connections for the STGD**

## FUNCTIONAL DESCRIPTION

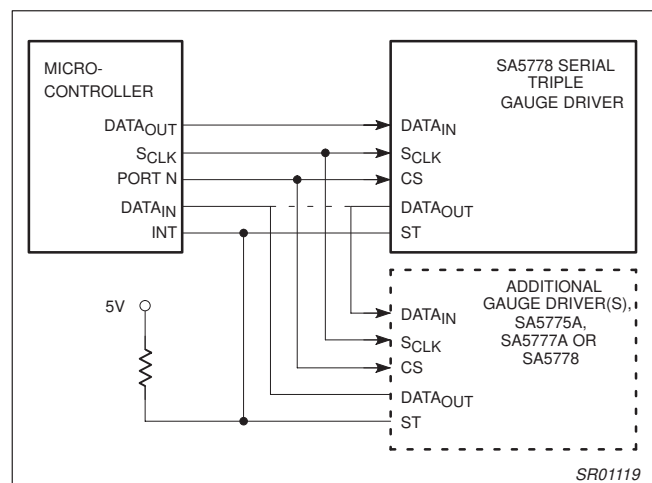
Figure 1 shows the pin-out of the STGD, which is packaged in an SO-28 pin package, enhanced for improved thermal management. Four pins on each side of the package serve as a heat spreader to remove heat from the die, and also function as the ground connection. The recommended mounting includes an area of copper on the PC board to aid in thermal management.

Figure 2 is a block diagram of the STGD. A serial interface connects the STGD to the microcontroller. A data output pin is provided to permit the STGD to be wired in series with other Philips air core gauge drivers such as the Serial Gauge Driver, SA5775, and the Dual Gauge Driver, SA5777 or additional STGDs. Status information may be passed back to the microcontroller via a status output, or via the serial interface.

Figure 3 shows the connection of the STGD in a typical application.

## APPLICATION INFORMATION

Figure 4 demonstrates the connections between the STGD, the microcontroller, and optionally additional gauge drivers such as the SGD and DGD. With an active high on the chip select input (CS), data is shifted into the STGD through DATA<sub>IN</sub> on the rising edge of S<sub>CLK</sub>. Several gauge drivers may be wired in series using a common chip select and clock line, when more than three gauges are needed. The DATA<sub>OUT</sub> pins are cascaded to the DATA<sub>IN</sub> pins of the following gauge drivers. Status information can be returned to the microcontroller via the ST pins of each gauge driver. These are open-drain, active low outputs, which may be wire OR'ed together to signal that a fault, such as a thermal shut down, has occurred within one of the gauge drivers. This pin may be connected to a microcontroller port pin for polling in software, or may be connected to an external interrupt input to cause entry into an interrupt service routine. The STGD, may also pass status information back to the microcontroller serially. The rising edge of chip select loads status information into the shift register for the first four bits that will be shifted out of the STGD by the shift clock. Figure 11 shows the data bits within the shift register. A low on the ST pin signals that one or more status bits have been set in the status register. A high indicates all status bits are reset. The status output bits include minor gauge over current, major gauge over current, thermal shutdown and RUN. Gauge data is captured in latches by the falling edge of the chip select.



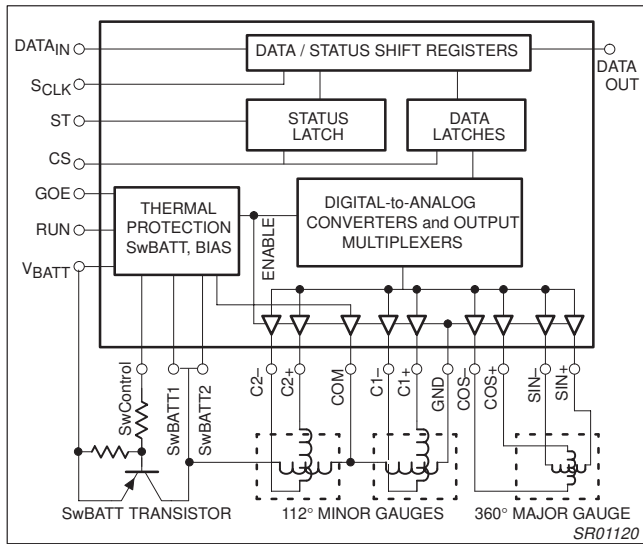
**Figure 4. Serial Communications Between STGD, Microcontroller and Other Gauge Drivers**

Figure 5 shows the gauge connections to the STGD. The major gauge, G1, supports full 360° operation with two coils driven. The seven least significant bits of the gauge information are converted to an analog level by digital-to-analog converter. The display range is divided into eight sections, two sections per quadrant. The coils are driven with a Sine/Cosine approximation. The three most significant bits of gauge display information control the multiplexer to select which coil is fed by the DAC and which coil receives a fixed bias. The multiplexer also determines the polarity of the voltages supplied to the coils.

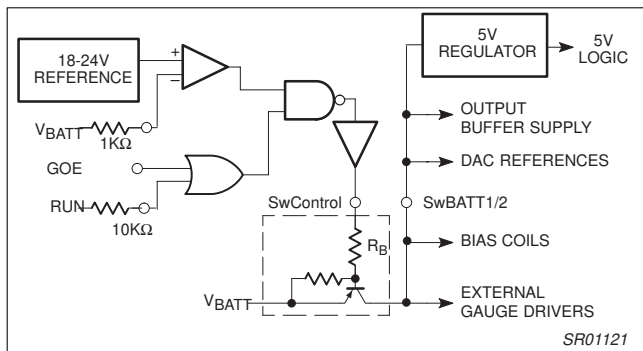
The minor gauges, G2 and G3, each have one coil driven by a DAC. The other coils of each gauge are wired in series with the switched battery supply to supply the bias. The switched battery supply is turned off during over voltage conditions. Only 9-bits of information are required for the minor gauges, however, 10-bits are shifted through the part to maintain compatibility with the SGD and DGD. Hence, all gauges, both major and minor, are supplied with 10-bit data for consistency.

# Serial triple gauge driver (STGD)

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**Figure 5. Gauge Connections to the STGD**



**Figure 6. Gauge Enable/Standby Circuit and Over Voltage Protection Circuit**

Figure 6 shows the protection and gauge enable logic for the STGD. The battery supply voltage  $V_{BATT}$  is monitored, and if the supply exceeds the specified operating range, the STGD is put in a shutdown mode in which the output buffers are disabled. The STGD will also enter the shutdown mode by excessive die temperature, and will return to normal operation when the die temperature decreases to within specified limits. Thermal shutdown may occur at  $V_{BATT}$  supply voltages over 16V at high ambient temperatures near 105°C. Internal logic will continue to function and status may be read out to determine the source of the shutdown. The STGD may be

placed in a standby mode with a low on both the GOE and RUN input pin. In this mode, battery current drain is minimized.

The SwBATT1 and SwBATT2 inputs are the supply for the DACs, and the output buffers driving the coils including the COM output which stabilizes the voltages applied to the bias coils of the minor gauges. Both SwBATT1 and SwBATT2 should be connected to the collector of the control transistor as these inputs are not connected internally and supply different portions of the circuit. This switched battery supply is protected from voltages exceeding the specified operating range and is controlled by the SwCONTROL output. This supply may optionally be used to supply additional circuits which operate from unregulated battery supplies but which need protection from over voltage transients. Typical devices which may benefit from this protection include the Serial Gauge Driver, SA5775A and Dual Gauge Driver, SA5777A, which are often used in conjunction with the STGD in 4 and 5 gauge applications.

This switched battery supply is turned off when the STGD enters the standby mode in response to the RUN and GOE inputs both being low, or a  $V_{BATT}$  supply exceeding the specified operating range. The switched battery supply depends on the RUN signal to prevent undesired needle movement on the minor gauges when going from standby to active mode. This movement would otherwise occur if the voltage to the fixed bias coils of the minor gauges was switched on before the coil voltages provided by the DACs within the STGD were defined. The start up jump is prevented as follows. In the sleep mode the switched battery supply is off, and the gauge drive outputs of the STGD are in a high impedance state. The gauges are in their zero position from the previous power-down sequence. When the RUN input goes high, but the GOE is kept low, the STGD enters the start up mode in which the minor gauges are driven to zero, the internal 5V regulator for the logic is turned on, and the switched battery supply is turned on to supply the bias coil and STGD output buffers. However, the output buffers for the major gauge remain in the high impedance output state. The microcontroller may load values into the STGD via the serial interface while GOE is low. When the microcontroller applies a high to GOE, the major gauge output buffers are enabled. When the RUN signal is removed the STGD continues to operate in the normal mode, however, the controlling microcontroller should also monitor RUN and, when it goes low, send a series of values to the STGD to move the needles to their zero positions before taking GOE low to put the part in the standby mode.

Table 1 describes the operation and control of the SwBATT supply, the output buffers, and the operations normally performed by the microcontroller. Normal operation of a vehicle will follow the sequence of the truth table from top to bottom. The RUN input is typically connected to the switched ignition voltage, while GOE is controlled by the microcontroller.

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Table 1. Truth Table

RUN Input 1=High	GOE Input 1=High	SwControl 1=ON	Swbatt1,2 Voltage	Minor Gauge Driver Outputs	Major Gauge Driver Outputs	System Status
0	0	0	Off	High Impedance	High Impedance	Standby mode
1	0	1	V <sub>BATT</sub>	Enabled (output forced to zero)	High Impedance	Start up mode, sets minor gauge driver to zero position, and disables major gauge driver. Load values into STGD via the serial port.
1	1	1	V <sub>BATT</sub>	Enabled	Enabled	Normal Operating mode. Periodically update gauge data as required by the application.
0	1	1	V <sub>BATT</sub>	Enabled	Enabled	Power down sequence. Load a series of values into the STGD to return needles to zero before power is removed.
0	0	0	Off	High Impedance	High Impedance	Returned to standby mode (same as first row of table)

## THERMAL MANAGEMENT AND POWER DISSIPATION

The power dissipated by the STGD has three components. The first term in the equation below represents the power dissipated in the STGD from current through the coil resistance. This component of the power dissipation is a function of both the battery voltage and the coil resistance. Most of the external loads such as the coils are resistive, so the current drawn by the output buffers is proportional to the supply voltage, resulting in power dissipation that is proportional to the square of the supply voltage for these circuits.

The highest power dissipation for a given coil driver will occur when the coil voltage is being driven to 50% of V<sub>BATT</sub>. Thus the power dissipated by each coil driver is (V<sub>BATT</sub>/2)\* (V<sub>BATT</sub>/2R<sub>C</sub>) or V<sub>BATT</sub>(V<sub>BATT</sub>/4R<sub>C</sub>). If the coil resistance of the two minor gauge coils and the two coils of the major gauge all have the same resistance, then the maximum total power dissipation of the drivers becomes 4\*V<sub>BATT</sub>(V<sub>BATT</sub>/4R<sub>C</sub>) or simply V<sub>BATT</sub>(V<sub>BATT</sub>/R<sub>C</sub>). Much of the internal analog circuits appears to the supply pins as a current sink and is represented by the second term. The current drawn by these circuits is relatively constant despite changes in supply voltage, resulting in power dissipation that is proportional to the supply voltage. Finally some power is dissipated in driving the external PNP transistor used to control the switched battery supply. The total power dissipation is a combination of these components and may be calculated from the formula:

$$P_D = V_{BATT}(V_{BATT}/R_C) + V_{BATT}(0.012) + V_{OL2}(V_{BATT} - V_{OL2} - V_{BE(PNP)})/R_B$$

Where:

P<sub>D</sub> = Power dissipation in watts

V<sub>BATT</sub> = Battery supply voltage in volts

R<sub>C</sub> = Coil resistance in ohms at ambient temperature including any self heating effects

V<sub>OL2</sub> = Output low voltage of the SwCONTROL pin as specified in the DC Characteristics

V<sub>BE(PNP)</sub> = The V<sub>BE</sub> drop of the external PNP transistor

R<sub>B</sub> = Resistor in series with base of external PNP transistor.

The minimum value of R<sub>B</sub> = V<sub>BATT</sub>MAX I<sub>OL</sub> = 16/0.050 = 320 Ω

The actual value used is dependent on the current needed to keep the PNP in saturation.

All gauges at 45° to a quadrant axis, as this is the highest internal power dissipation position.

If only the nominal coil resistance is known at a given nominal ambient temperature such as 25°C, the coil operating resistance at a high temperature ambient may be calculated using the following formula:

$$R_{CA} = R_{CN} (1 + (0.4\%/^{\circ}\text{C}) * ((T_{SH} + T_{amb}) - 25^{\circ}\text{C}))$$

Where:

R<sub>CA</sub> = Resistance of Coil at Ambient temperature, including self heating

R<sub>CN</sub> = Nominal Resistance of Coil at 25°C, without self heating

T<sub>amb</sub> = Ambient temperature, °C

T<sub>SH</sub> = Self heating of coil, °C

0.4%/°C = Resistance increase coefficient for copper

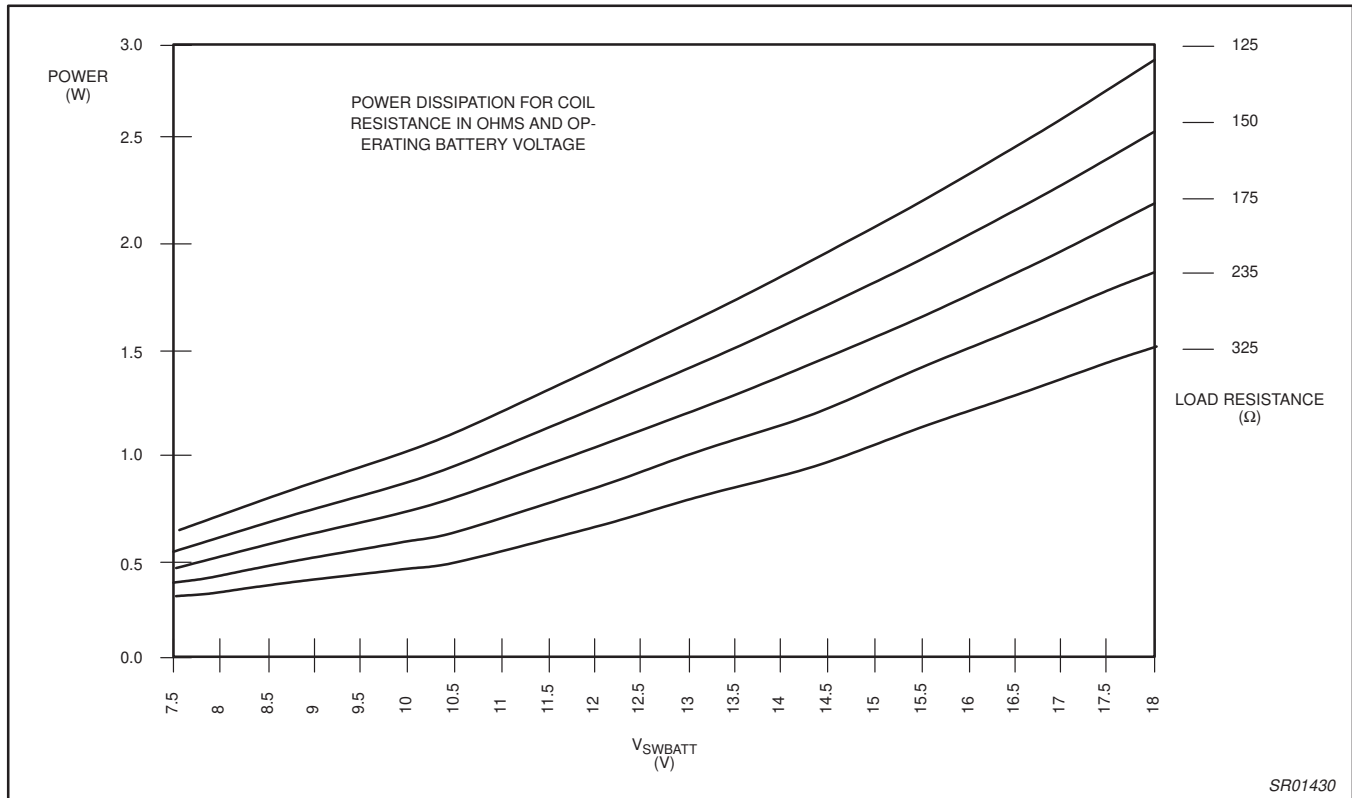
Figure 7 shows power dissipation plotted as a function of coil resistance and voltage. Since coil resistance is a function of temperature, the maximum power dissipation plotted will only occur at the lowest specified operating temperature. The power dissipation is lowest at the highest ambient temperature because of the increase in coil resistance with temperature.

This maximum power dissipation will only occur during a fault condition in which the system voltage rises to 18V, generally because of a failed voltage regulator controlling the vehicles battery voltage. Power dissipation will be lower when air core meter movements with higher nominal coil resistance are used.



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**Figure 7. Power Dissipation of the STGD as a Function of Coil Resistance and Operating Voltage**

The STGD is specified to operate up to  $V_{BATTmax}$ . The over voltage shutdown circuit will turn off the output buffers and the switched battery supply when the battery voltage reaches  $V_{OVSD}$ . Over temperature conditions will also cause the output buffers to be disabled.

The STGD employs a thermally enhanced SO-28 package. The center four pins on each side are fused to the die pad to create a path for removal of heat from the package to the copper foil on the PC board. An area of copper foil is required on the PC board for heat dissipation at higher power dissipation levels.

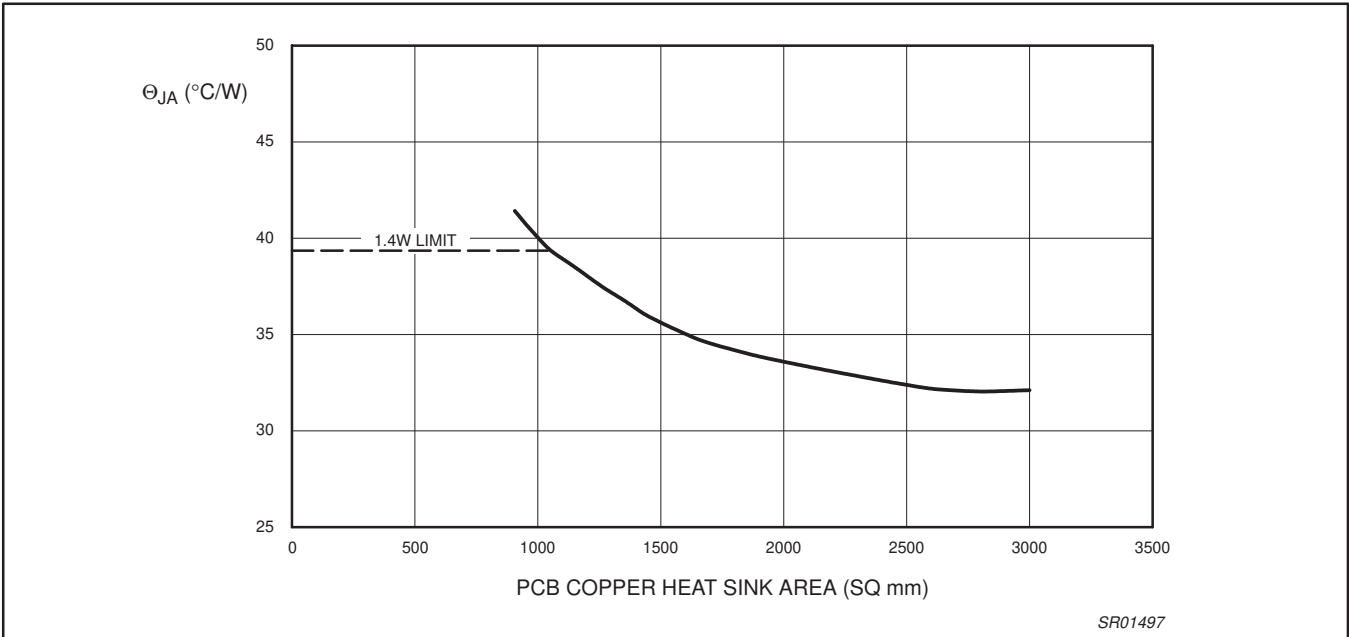
In order to determine the size of the copper foil required, both thermal testing and thermal modeling were used. The effective  $\Theta_{JA}$  (thermal resistance, junction to ambient) was determined using both single and double sided PCBs with heat-sinking copper foil areas. Figures 8 and 9 show the effect of PCB copper foil area on the effective thermal resistance of the STGD part/PCB system.

Figure 8 shows the thermal resistance of the STGD mounted on a PC board with heat-sinking copper on the component side only. Figure 9 is a similar plot for a two sided PC board (same size copper areas on each side). Both plots assume a 60 x 60 x 1.57 mm FR4 board with varying square-shaped sizes of 2 oz. copper. The two sided board also assumes 8 thermal bias with 0.36 mm<sup>2</sup> cross section.

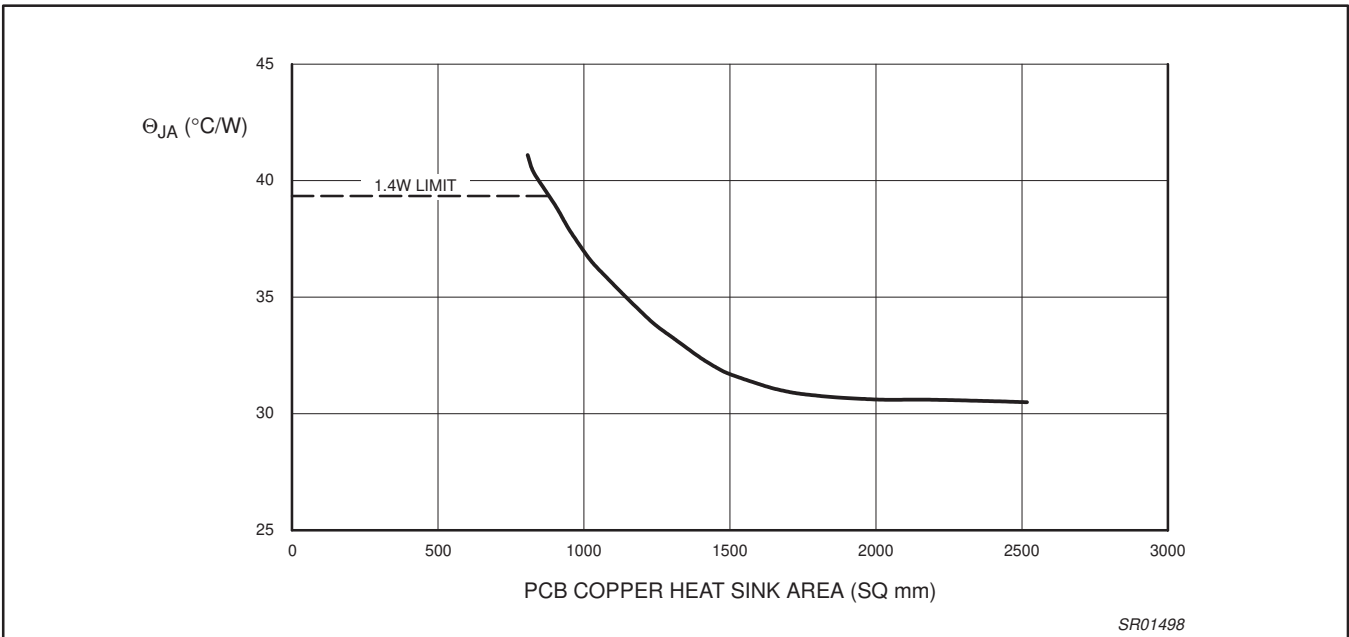
It is important to note that at such a high ambient temperature (worst case of 105°C assumed), radiation is just as significant as convection in the dissipation of heat. Good radiation is highly dependent on the emissivity of the heated surface, so the thermal radiation properties of the copper foil should be considered. Bare, clean copper is a good thermal conductor, but it has a low emissivity, and is therefore a bad radiator. It is recommended that the copper areas intended for heat dissipation be left covered with solder mask or otherwise blackened to increase the emissivity, thereby improving the heat radiating ability of the board.

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**Figure 8.**  $\theta_{JA}$  for SO28 with 8 Fused Pins  
One-sided PCB (2 oz. Copper),  $e = 0.9$ ,  $T_{amb} = 105^{\circ}\text{C}$ ,  $P = 1.4\text{--}1.8\text{W}$



**Figure 9.**  $\theta_{JA}$  for SO28 with 8 Fused Pins  
Two-sided PCB (2 oz. Copper),  $e = 0.9$ ,  $T_{amb} = 105^{\circ}\text{C}$ ,  $P = 1.4\text{--}1.8\text{W}$

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## Sample Calculations for Power Dissipation and Thermal Management

### Worst Case Example

The worst case example will occur when the STGD is operating at  $V_{BATTMAX}$  (16V, in the highest specified ambient temperature (105°C), and with the lowest specified coil resistance (171 ohms at 25°C). Typical coil self heating of 15°C is assumed.

Calculation of Coil resistance operating at 105°C ambient.

$$R_{CA} = R_{CN} (1 + (0.4\%W/^{\circ}C) * ((T_{SH} + T_{amb}) - 25^{\circ}C))$$

$$= 171 \times (1 + (0.4\% * ((15 + 105) - 25)))$$

$$= 236 \text{ Ohms at } T_{amb} = 105^{\circ}C, \text{ with } 15^{\circ}C \text{ of self heating.}$$

Calculation of STGD power dissipation at 16 volt operation.

$$P_D = V_{BATT} (V_{BATT}/R_C) + V_{BATT} (0.012) + V_{OL2} (V_{BATT} - V_{OL2} - V_{BE(PNP)}) / R_L$$

$$= 16(16/236) + 16(0.012) + 1.5(16 - 1.5 - 0.5)/320$$

$$= 1.085 + 0.192 + 0.066 \text{ Watts}$$

$$= 1.34 \text{ Watts}$$

### Required board area and Junction Temperature calculation

The maximum junction temperature desired is 150°C. The permissible temperature rise and required  $\Theta_{JA}$  may be calculated as:

$$\Delta T = T_J - T_{amb}$$

$$\Theta_{JA} = \Delta T / P_D$$

Where;  $\Delta T$  = Temperature rise in °C

$P_D$  = Power dissipation

$T_J$  = Junction Temperature

$T_{amb}$  = Ambient Temperature

$$\Delta T = T_J - T_{amb} = 150 - 105 = 45^{\circ}C$$

$$\Theta_{JA} = \Delta T / P_D = 45^{\circ}C / 1.34 \text{ watts} = 33^{\circ}C/W.$$

From Figure 8, the copper area required, using a single sided board, to keep the junction temperature within limits is approximately 2200 mm<sup>2</sup>. Figure 9 shows 1200 mm<sup>2</sup> is required on each side of a double-sided board.

The above example illustrates the worst case situation of the STGD operating in at a maximum battery voltage, with the lowest nominal coil resistance (171Ω at room temperature), and at the highest ambient temperature. This will produce the highest junction temperature. At lower ambient temperatures the power dissipation may be higher because the coil resistance is decreased, however the junction temperature will be lower.

### Serial Interface

Figure 10 demonstrates the serial interface timing referenced in the AC specifications. Figure 11 shows the order of information transfer through the serial interface. On a low to high transition of the CS pin, status information replaces the four most significant bits of data in the shift register and are the first bits shifted out. Output data is changed on the falling edge of  $S_{CLK}$ , while input data is captured on the rising edge of  $S_{CLK}$ . Major gauge data is loaded first, starting with the most significant bit, followed by minor gauge 1 data then minor gauge 2 data.

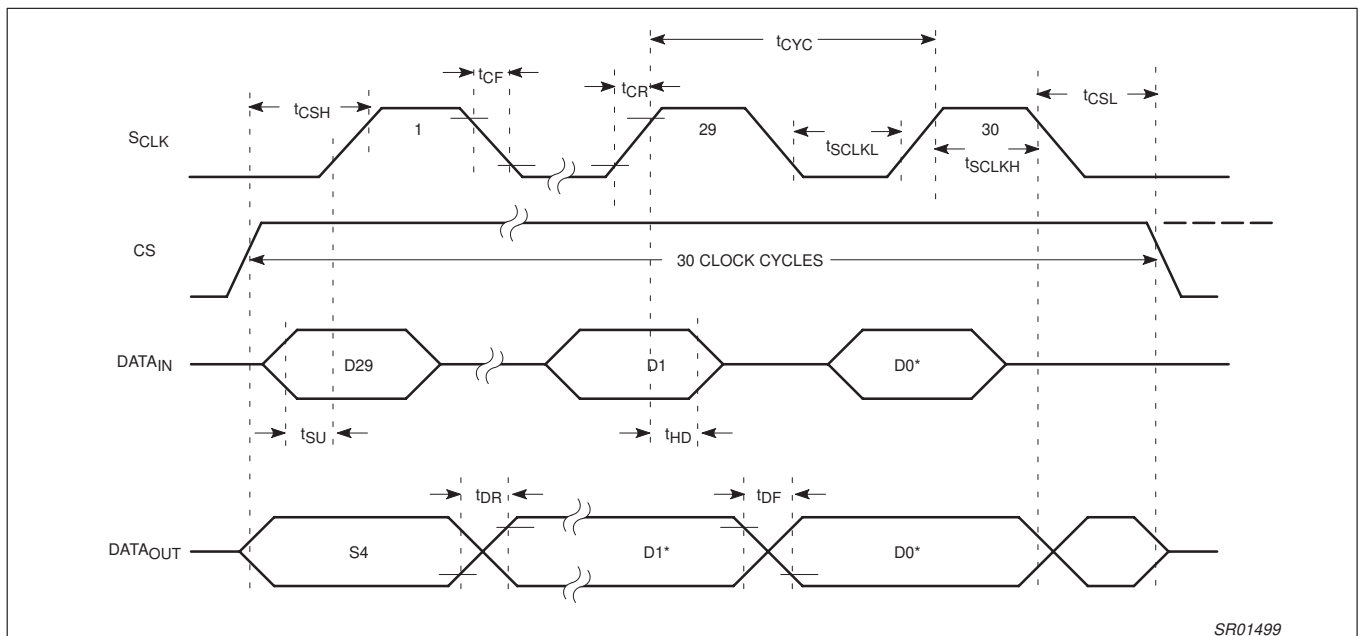


Figure 10. Serial Interface Timing

SR01499

# Serial triple gauge driver (STGD)

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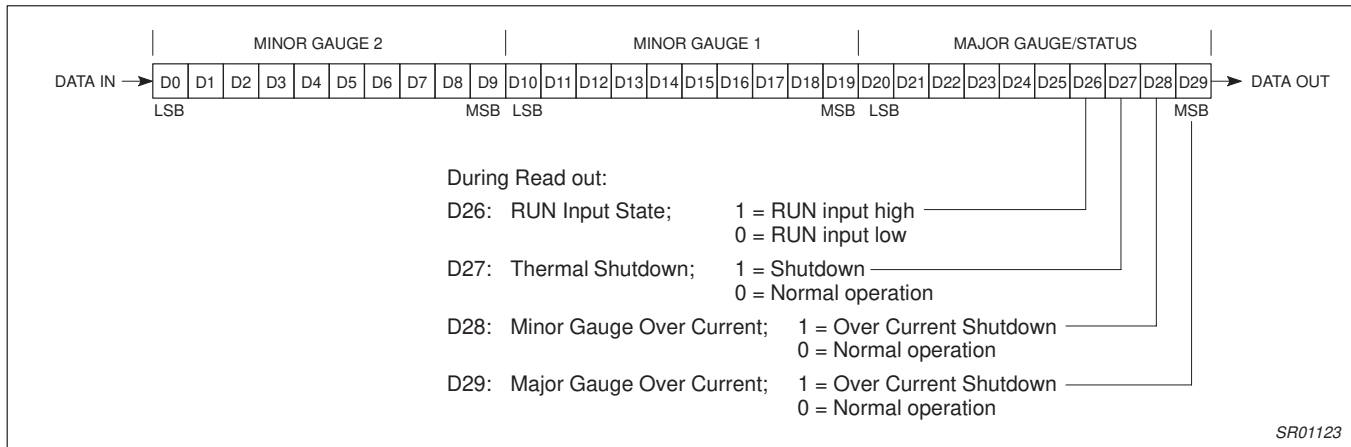


Figure 11. Internal Shift Register

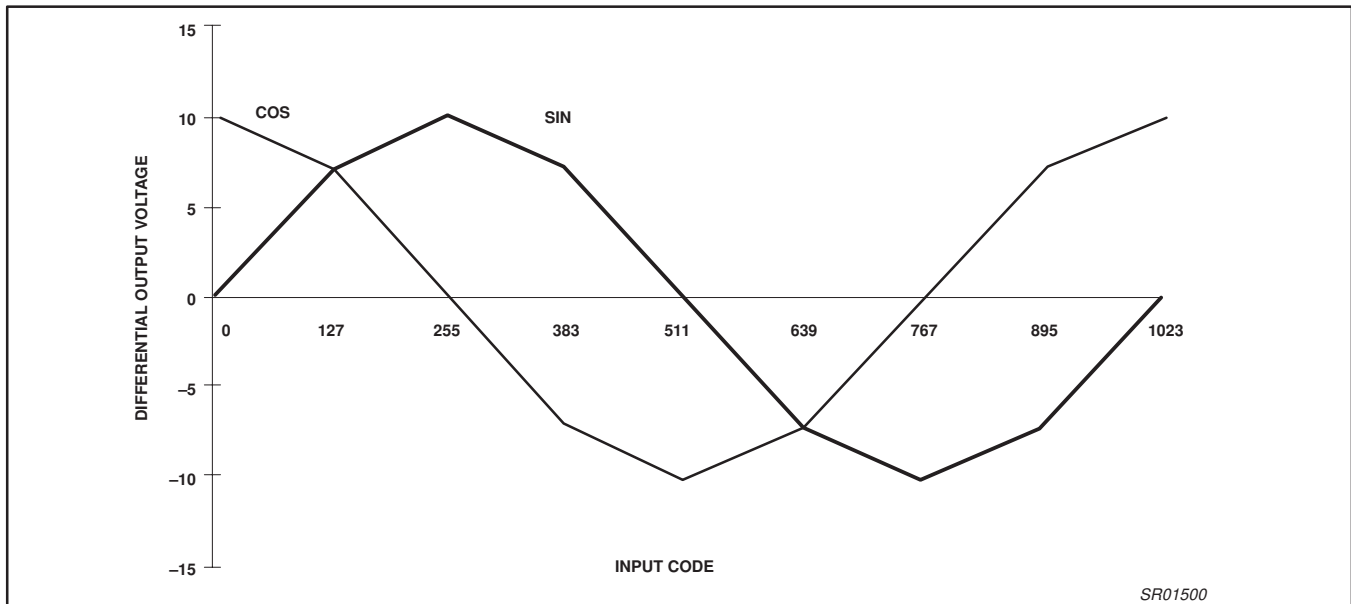


Figure 12. Major Gauge Output Voltages ( $V_{SWBATT} = 14V$ )



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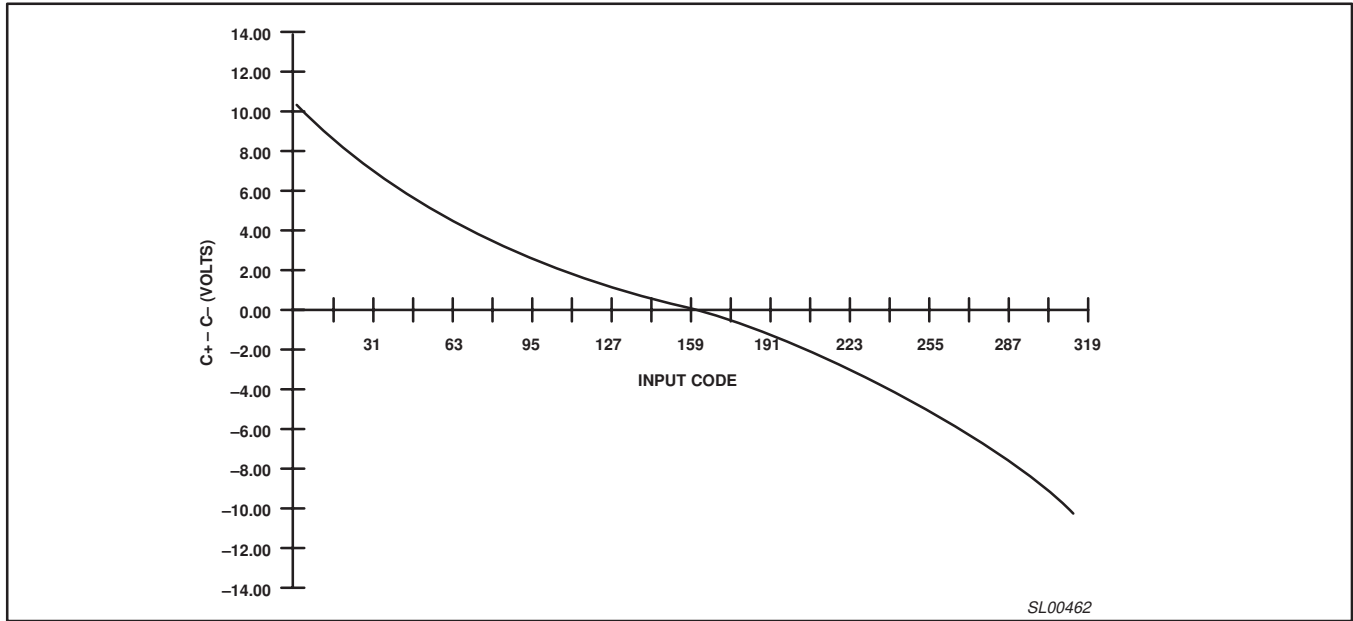


Figure 13. Typical Minor Gauge Output Voltage vs. Input Code ( $V_{SWBATT} = 14V$ )

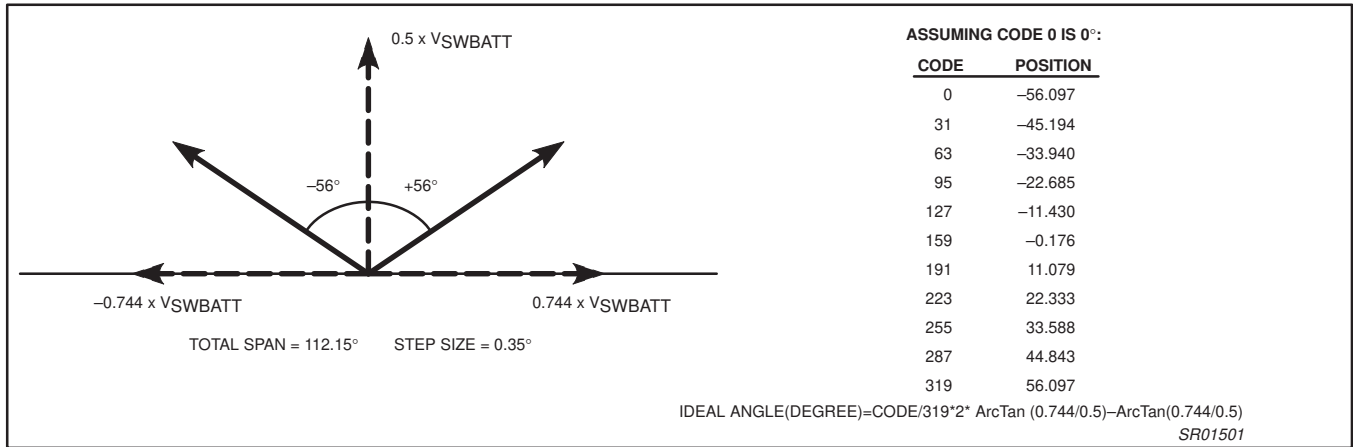


Figure 14. Minor Gauge Total Span

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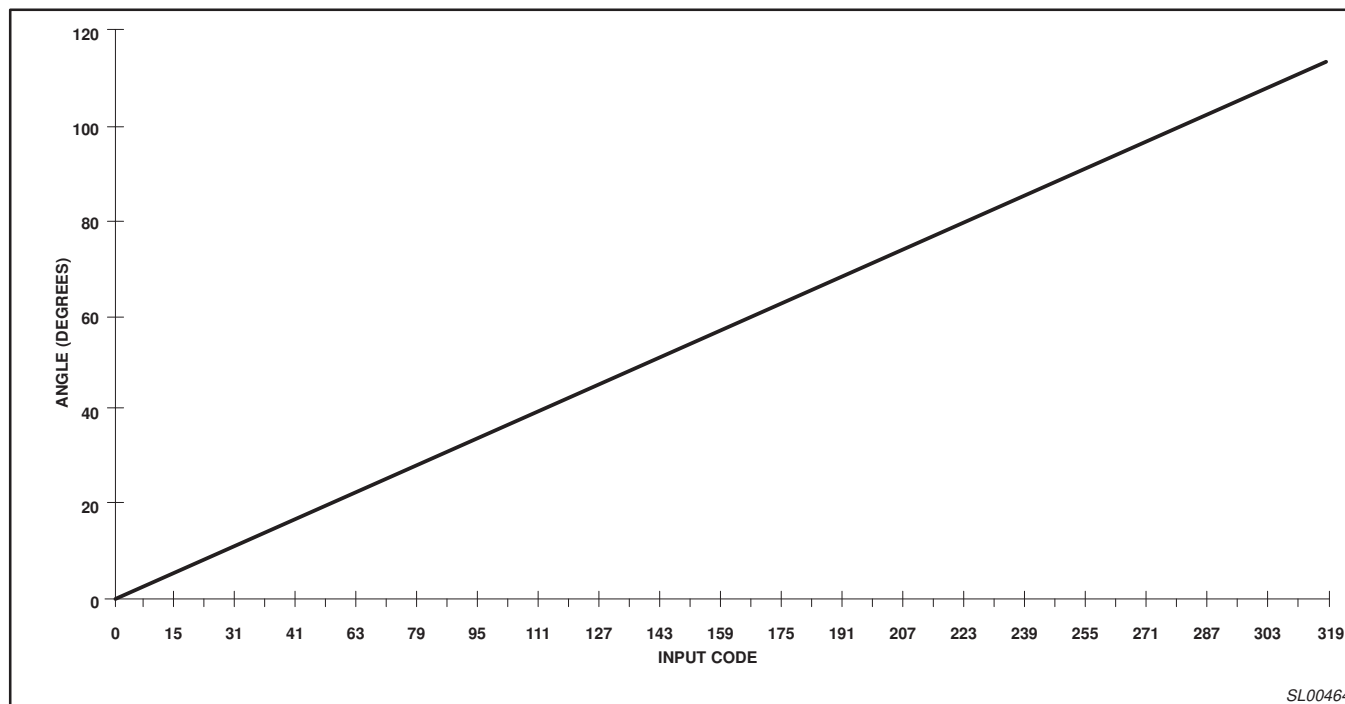


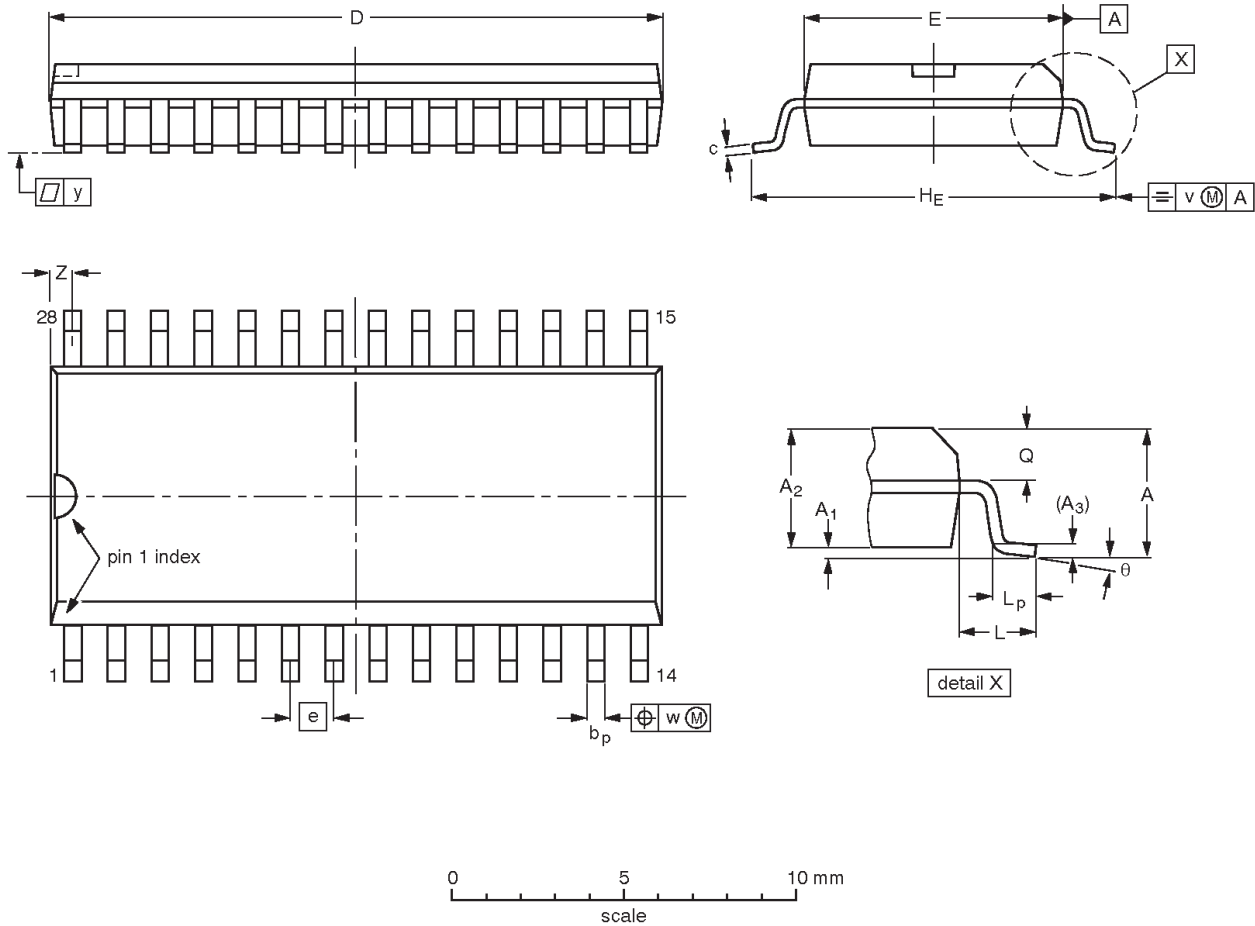
Figure 15. Meter Position (degrees) vs. Input Code for Minor Gauges

# Serial triple gauge driver (STGD)

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**SO28: plastic small outline package; 28 leads; body width 7.5mm**

**SOT136-1**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	z <sup>(1)</sup>	$\theta$
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	18.1 17.7	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8° 0°
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.71 0.69	0.30 0.29	0.050	0.419 0.394	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

**Note**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT136-1	075E06	MS-013AE				95-01-24 97-05-22

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## NOTES



## Serial triple gauge driver (STGD)

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## Data sheet status

Data sheet status	Product status	Definition [1]
Objective specification	Development	This data sheet contains the design target or goal specifications for product development. Specification may change in any manner without notice.
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