S29S Series

Application Manual

S29S1T0D24Z　　**S29S1T0D24ZM**　　**S29S1T0D24ZJ**

■ Overview

S29S Series is a closed-loop type and through-type current sensor.

The rated current is 1000 A and the maximum current is ±2100 A. (Within 3 seconds)

This series has the input and output format of a connector type and variations as shown in table 1.

Table 1: Variation in input and output connector

Model number of current sensor	**S29S1T0D24Z**	**S29S1T0D24ZM**	**S29S1T0D24ZJ**
Model number of input and output connector [Old Model number]	39-28-8040 [5566-04A-210]	38-00-6293 [6410-03C(102)]	BH3P-VH-1
Connecter manufacturer	Molex	Molex	JST

■ Characteristics

- Through-type supply system of the current to be measured.
- Closed-loop-type circuit configuration.
- Input/output of connector-type format with panel mounting structure.
- Power-supply voltage can be used in the range between ±15 V and ±24 V.
- Output in the form of current, given as 1/5000 of the current to be measured.
- Very high accuracy output current of within ±0.4%.
- Excellent output linearity of within ±0.1%.
- Fast response: Step response (response speed $\frac{di}{dt}$) of less than 1 μs.
- Withstand voltage: AC 4000 V for 1 minute
- Satisfies conformity safety standard EN50178;1997.

■ Use

- Power monitoring equipment for solar photovoltaic power generation, etc.
- Current measurement of a generator

■ **Format**

S29S 1T0 D 24 □□

- □□ — Connector: variation (See Table 1)
- 24 — Power-supply voltage 24: 24 V
- D — Power-supply type D: Dual power supply
- 1T0 — Rated current 1T0: 1000 A
- S29S — Series name S29S

■ Standard connection diagram

S29S1T0D24Z

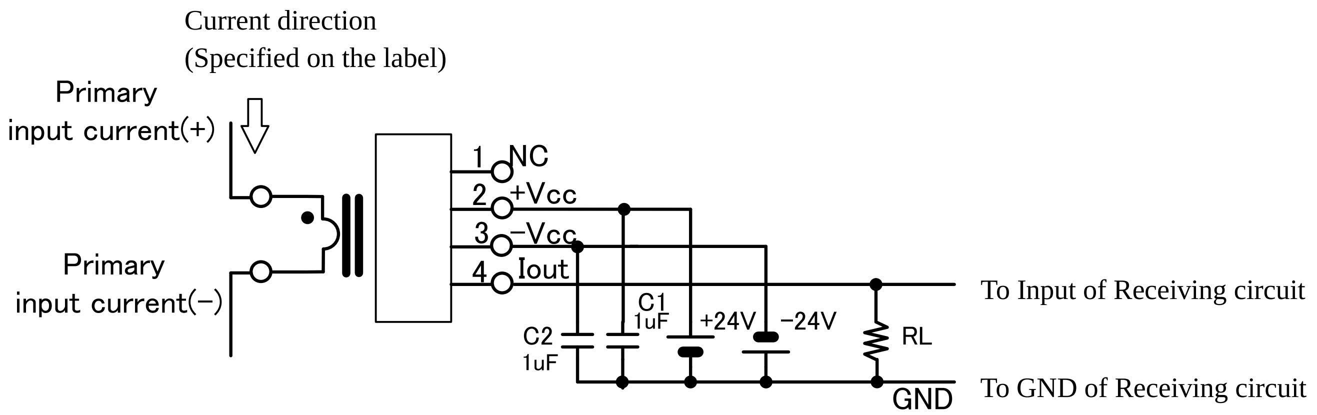
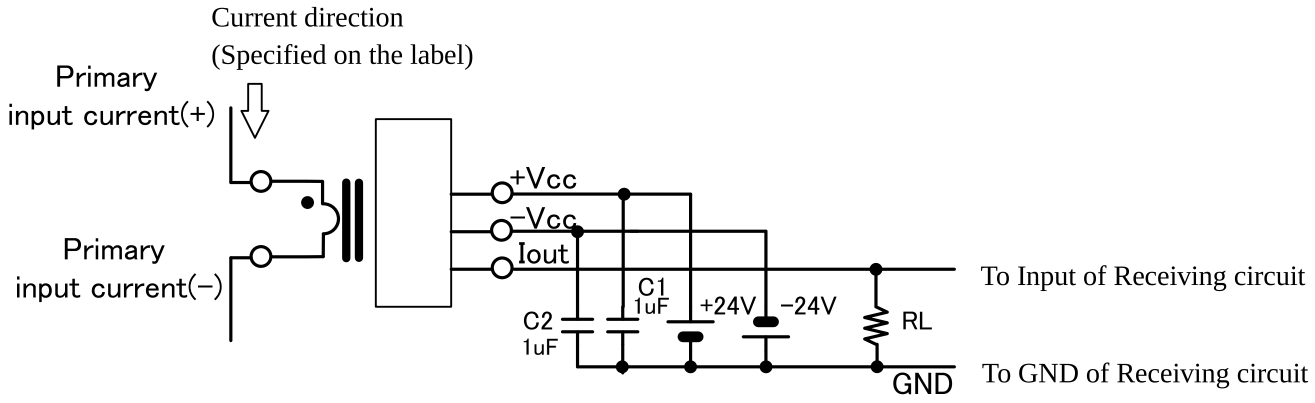


Fig. 1: S29S1T0D24Z Standard connection diagram

S29S1T0D24ZM

S29S1T0D24ZJ



Terminal number

Name	S29S1T0D24ZM	S29S1T0D24ZJ
+Vcc	1	3
-Vcc	3	1
Iout	2	2

Fig 1-2: S29S1T0D24ZM/S29S1T0D24ZJ Standard connection diagram

■ **Description of input/output terminals:** S29S1T0D24Z/S29S1T0D24ZM/S29S1T0D24ZJ

Table2: Description of input/output terminals

Terminal number	Terminal name	Description	Remarks
See Fig. 1-1 and Fig. 1-2	NC		
	+Vcc	Positive power-supply terminal. Apply +15 V ~ +24 V.	
	–Vcc	Negative power-supply terminal. Apply –15 V ~ –24 V.	
	Iout	Output terminal. The current output between this terminal and GND is 1/5000 of the current to be measured. A resistor can be inserted between this terminal and GND for measuring the voltage corresponding to the current to be measured.	*
	Primary current (+)	The plus side of the primary current (measured current). When the primary current flows in the direction of the arrow (⇒) on the label, the output current has polarity in the direction from the output terminal (Iout) to GND.	Through-hole
	Primary current (–)	The minus side of the primary current (measured current).	Through-hole

* The standard value of output current $Iout = \frac{1}{5000} \times I + Iof$.

I : Current to be measured　　Iof : Offset current $(= 0A typ)$

■ Description of basic characteristics

The S29S Series current sensor is used for the measurement of 1000-A-class current and outputs 1/5000 of the current to be measured from the output terminal. The internal structure is composed of a core (a magnet) having a through-hole and an electronic circuit. The electronic circuit is composed of a negative feedback coil constituting a closed loop and a phase compensation circuit for stable operation of the amplifier and the closed loop. The power-supply voltage is required for both plus and minus directions. The power-supply voltage should lie within the range of ±15 V and ±24 V.

The current to be measured is passed through a bus bar or a cable through the through-hole of the sensor. The magnetic flux generated by the current to be measured converges to the built-in core (a magnet), and the built-in amplifier energizes the canceling current to the negative feedback coil in such a way that the generated magnetic flux becomes extremely small, i.e., approximately 0 Tesla. That is, a current is supplied to the negative feedback coil so as to cancel the magnetic flux generated by the current to be measured. The magnetic flux of the core (a magnet) is proportional to (current) times (number of turns). The number of turns of the negative feedback coil is 5000 and the current to be measured is passed through the through-hole once (one turn). Therefore, when 1/5000 of the current to be measured is supplied to the negative feedback coil, the magnetic flux of the core (magnet) is canceled and approaches zero. The current applied to the negative feedback coil for the cancellation of magnetic flux is output from the output terminal. In this way, the output current is 1/5000 of the current to be measured. The output current can be measured by converting it into a voltage with a measuring resistor connected between the output terminal and GND. The output polarity is in the direction in which the current flows out from the output terminal when the current to be measured is supplied in the direction of the arrow described on the sensor body. That is, when the current to be measured is supplied in the direction indicated by the arrow, the measuring resistor outputs a voltage of plus polarity. The sensitivity (output current/current to be measured) of the current sensor of the closed-loop configuration is 1/(number of turns of negative feedback winding). It is little affected by fluctuations in the sensitivity of the Hall element and the gain of the AMP, but is determined by the number of turns of the coil. Therefore, the closed-loop S29S Series current sensor can achieve a high accuracy in the output within ±0.4% and output linearity within ±0.1%.

Because the current output from the output terminal acts as a current source, it is negligibly affected by the wiring resistance from the output terminal of the sensor to the measuring resistor. Thus, accurate current measurement is possible by paying attention to the influence of the accuracy of the measuring resistor.

This current sensor operates in a manner similar to that of a current transformer so that a sharp change in the current can be measured. When the current to be measured changes stepwise, high-speed response is possible. In fact, when the current to be measured rises at the rate of 100 A/μs, the measured value reaches 90% of the target value within 1 μs.

This sensor has a panel-mounting structure and a connector structure for power-supply and output terminals. Three kinds of variations are available for the connector.

■ Block diagram (±15 V~ ±24 V dual power-supply type)

S29S1T0D24Z

S29S1T0D24ZM

S29S1T0D24ZJ

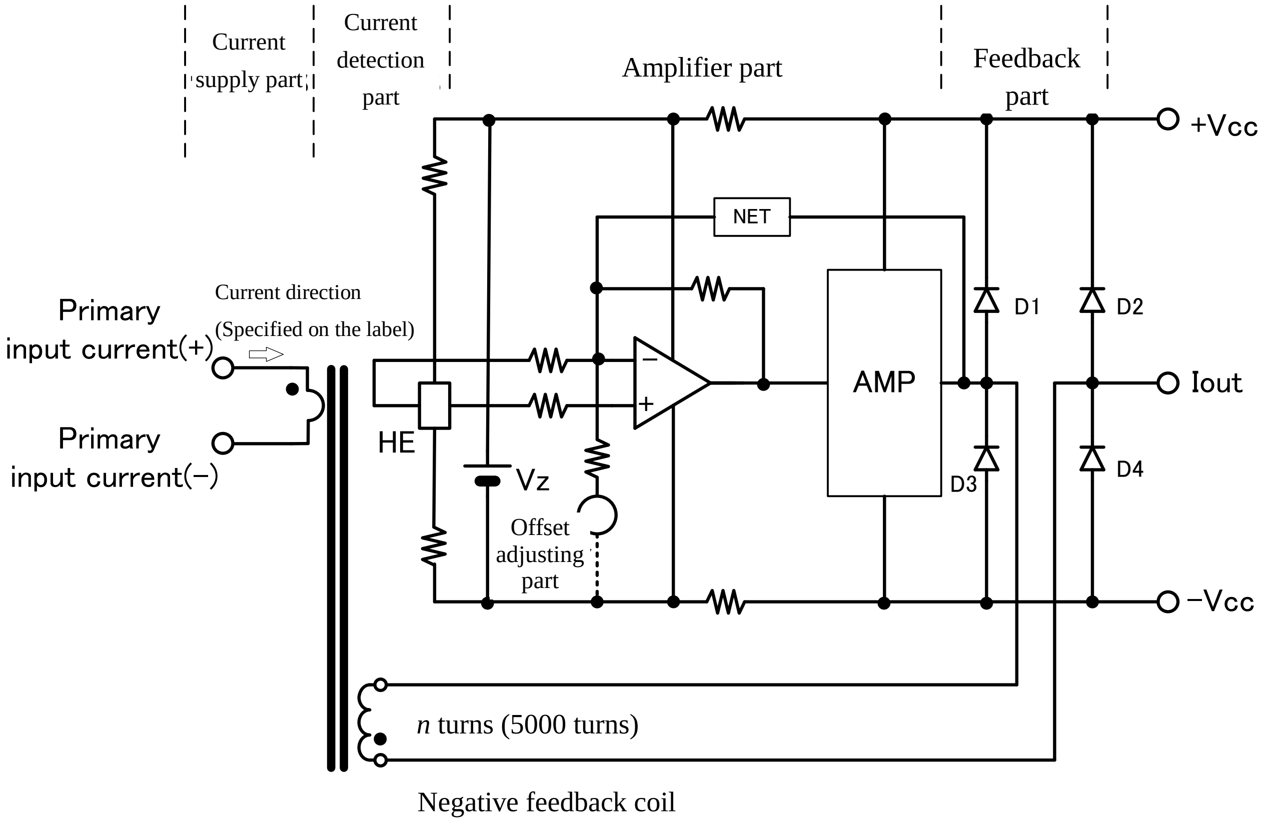


Fig. 2: S29S Series: Internal block diagram

■ Description of block diagram

Current-flowing unit

The current-supply part consists of a bus bar or electric wire that passes through the through-hole in the sensor body. The current to be measured is supplied to the bus bar or the electric wire passing through the through-hole. The magnetic flux generated by the current to be measured is concentrated on the core, which has high magnetic permeability. A Hall element is inserted in the core as a magnetic-detection element. The magnetic flux of the core is detected and converted into voltage. The bus bar or electric wire generates heat owing to its own resistance component (copper loss). Choose either a bus bar or electric wire corresponding to the magnitude of the energizing current such that the temperature of the sensor does not exceed the specified value by heat radiation of the current even when the ambient temperature reaches the allowable maximum value.

In addition to the copper loss caused by the penetrated bus bar and electric wire, heat is generated owing to iron loss (core loss) of the core built in the sensor. Each loss varies depending on various conditions such as the magnitude, frequency, and waveform of the current to be measured. The loss increases with the effective current value or with the dominant frequency component of the current to be measured. When the current contains high-frequency components other than those of the fundamental wave, iron loss further increases. Therefore, confirmation using an actual current is necessary.

Current-detection unit

The current to be measured (primary input current) is passed through the through-hole. The generated magnetic flux is focused by the core and applied to the magnetic-detection element (Hall element, HE).

On the other hand, approximately 1/5000 of the current to be measured flows in the negative feedback coil, and a magnetic flux is generated in the direction opposite to the magnetic flux generated by the current to be measured. Because the number of turns of the negative feedback coil is 5000, the magnetic flux of the core is canceled and becomes almost zero. The current flowing through the negative feedback coil is the same as the output current.

Therefore, the output current becomes approximately 1/5000 of the current to be measured. The magnetic-detection element (Hall element) detects net minute magnetic flux generated by the current to be measured and the negative feedback coil and converts it to voltage. The converted voltage is sent to the amplifier.

Feedback section of amplifier unit

The amplifier circuit amplifies the output voltage of the magnetic-detection element (Hall element) and converts it into current. The current from the amplifier circuit is sent to the feedback circuit. The feedback circuit provides current to the feedback coil. As a result, it constitutes a closed loop consisting of the magnetic-detection element ⇒ amplifier circuit ⇒ feedback circuit ⇒ negative feedback coil ⇒ core magnetic flux ⇒ (magnetic-detection element). See Fig. 3.

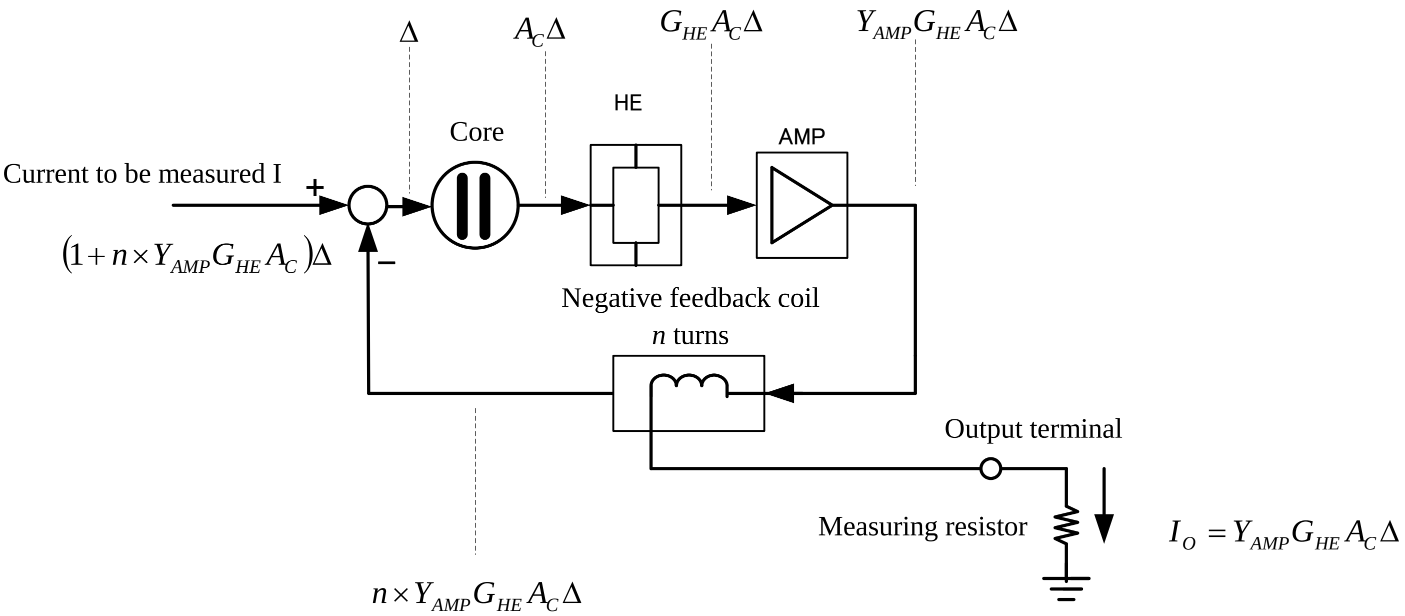


Fig. 3: Closed-loop block diagram

The effects on the core of the current *Io* flowing in the negative feedback coil and of the current *I* to be measured almost completely cancel each other because the effective current in the feedback coil is multiplied by the number of turns (ampere turn). The difference between these effective currents becomes equivalent to the net minute current Δ acting on the core.

The above-mentioned minute current generates small magnetic flux $A_C\Delta$ through the core of high magnetic permeability. The small magnetic flux $A_C\Delta$ is detected by the Hall element HE and is converted to voltage $G_{HE}A_C\Delta$. Furthermore, this voltage is amplified by AMP and converted into current $Y_{AMP}G_{HE}A_C\Delta$. This current $Y_{AMP}G_{HE}A_C\Delta$ is output from the output terminal as the output current. On the other hand, the same current flows through the negative feedback coil and acts as the current for canceling the current to be measured. When the number of turns of the negative feedback coil is *n*, the ampere turn is *n* × (current flowing through the negative feedback coil). Therefore, as a result of cancelation, the net minute current Δ that excites the core can be written as

$$\Delta = I - n\times Y_{AMP}G_{HE}A_C\Delta. \quad \text{Equation 1}$$

On the other hand, the output current is given by

$$I_O = Y_{AMP}G_{HE}A_C\Delta. \quad \text{Equation 2}$$

From Equations 1 and 2, therefore, the relationship between the output current and the current to be measured is obtained as

$$\frac{I_O}{I} = \frac{Y_{AMP} G_{HE} A_C \Delta}{\Delta + n \times Y_{AMP} G_{HE} A_C \Delta} = \frac{1}{n + \frac{1}{\mu}}, \qquad \text{Equation 3}$$

where $\mu \equiv Y_{AMP} G_{HE} A_C$.

Because μ of the closed-loop current sensor has a very large value, Equation 4 holds while maintaining high accuracy of the output current within ±0.4%.

$$\frac{I_O}{I} = \frac{1}{n} \qquad \text{Equation 4}$$

Because n=5000, the output current is 1/5000 of the current to be measured.

Current transformer

When the current to be measured suddenly changes, a current flows through the negative feedback coil in accordance with Lenz's law in such a way that the magnetic-flux change of the core caused by the current to be measured is canceled. This current is 1/5000 of the change of the current to be measured, and becomes the output current. When the current to be measured increases as shown by ⇒ in Fig. 4, the current of the negative feedback coil increases in the → direction, is output from the output terminal, flows from the measurement resistor *RL* to GND, and returns from the minus terminal to the negative feedback coil.

Because the output current returns from the power supply terminal to the negative feedback coil via GND, it is necessary to shorten this path. When a transient current of the output current flows, C1 and C2 are recommended to be 10 μF or more.

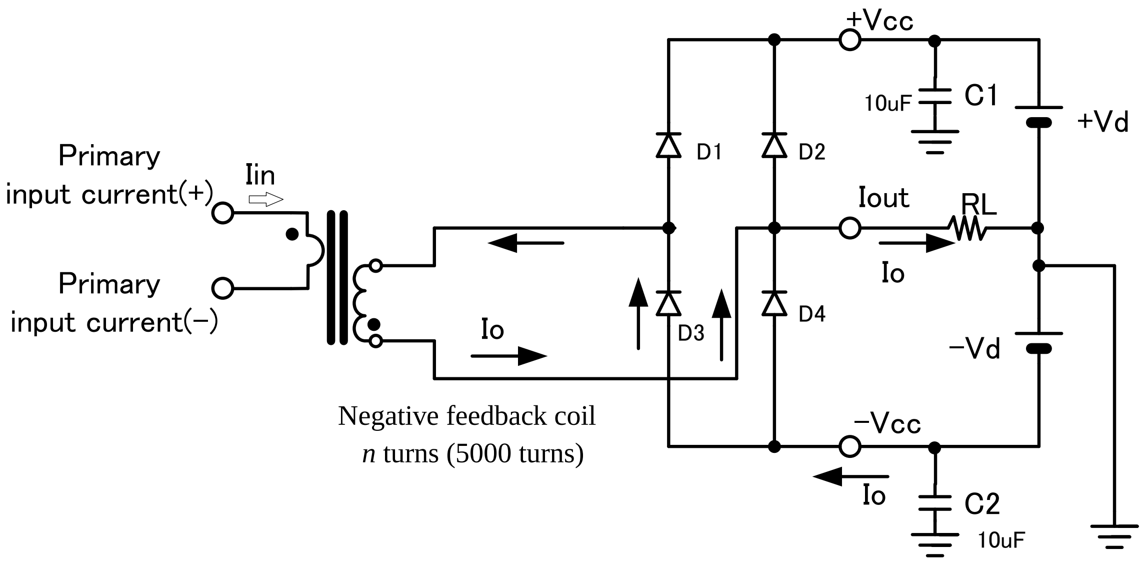


Fig. 4: Equivalent circuit of current transformer operation

Offset adjustment unit

The offset current is a reference of the output current and is an output current when the current to be measured is 0 A. For the S29S Series, the offset current is 0 A.

The main origin of a possible deviation of the offset current from the standard value of 0 A lies in the fact that the Hall element HE, which is the magnetic sensing element, can have an offset voltage. The offset voltage of the Hall element is a minute voltage output even in the absence of applied magnetic flux. A minute output current generated by this offset voltage is the origin of the deviation of the offset current. Deviation of the offset current can also be caused by the amplifier section in addition to the Hall element. Before the product is actually shipped, adjustment is made, using the offset adjusting part, in such a way that the overall offset is comprehensively canceled out and falls within a predetermined deviation.

■ Application

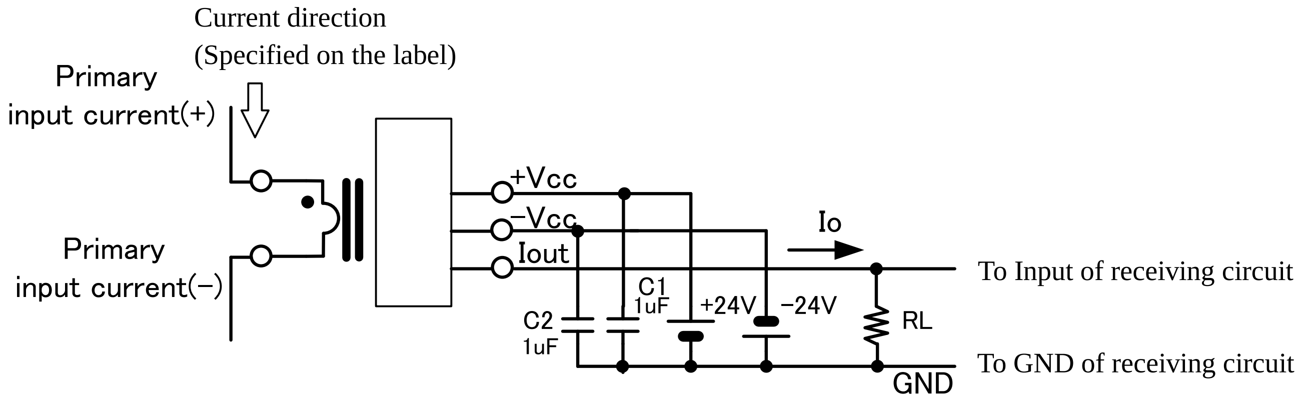


Fig. 5: Application

[Note]

The application shown below is not within the assurance standard of the S29S Series current sensor. In other words, the accuracy of the application and the performance corresponding to the parameter values of the parts shown below are not guaranteed. Therefore, when selecting circuits and component parameters during the design of actual products, sufficient evaluation based on careful consideration of safety and the stability of characteristics is necessary.

Basic operation

This current sensor converts the current to be measured into output current given as 1/5000 of the current to be measured. The output current Io in Fig. 5 flows through the measuring resistor RL connected between the output terminal (*Iout*) and GND. First, the voltage across the measuring resistor RL is measured, then the output current Io is calculated, and finally, the current to be measured Iin is obtained as

$$Iin = 5000 \times I_O = 5000 \times \frac{V_{RL}}{RL} , \qquad \text{Equation 5}$$

where

V_{RL} is the voltage between the terminals of the measuring resistor RL.

The output current Io flowing through the measuring resistor RL passes from the positive power supply through the AMP circuit to the measuring resistor RL, and returns to the power supply via GND.

Therefore, the ±24 V power supply is required to have sufficient capacity to supply the output current I_O plus the current consumed by the sensor.

The current to be measured Iin can be calculated from the voltage V_{RL} across the measuring resistor RL using Equation 5.

Measuring resistance RL

The measuring resistance RL is restricted by Equation 6 for a given power-supply voltage and the maximum current to be measured I_{MAX}. As shown in Fig. 6, the voltage at the output terminal decreases from each supply voltage by a fixed voltage v_{RE}, because of Q1 and Q2 in the sensor, resistors R1 and R2 connected to the emitter, and operational constraints of the preamplifier. Therefore, this voltage difference given by v_{RE} should be properly considered, and the allowable voltage range of the output terminal Iout is within the range of $Vd - v_{RE}$ on the plus side and $-(Vd - v_{RE})$ on the minus side. For such reasons, the maximum value I_{MAX} of the output current and the measuring resistance RL are subject to the constraint given by

$$\left| \frac{I_{MAX}}{5000}(R_S + RL) + v_{RE} \right| \le Vd \,, \qquad \text{Equation 6}$$

where R_S is the DC resistance of the negative feedback coil (Ω),

v_{RE} is the necessary difference voltage from the power-supply voltage (V),

Vd is the absolute value of the positive and negative power-supply voltage (V),

RL is the measuring resistance (Ω),

and v_{RE} is considered to be about 1.2 V to 1.8 V.

Because R_S is the DC resistance of a copper wire, it has temperature characteristics. The resistance $R_S|_{T=t}$ at coil temperature t is given by

$$R_S|_{T=t^\circ C} \approx 40.2\{1 + 0.0043(t - 25)\}. \qquad \text{Equation 7}$$

Equation 7 gives

$$R_S|_{T=70^\circ C} \approx 40.2\{1 + 0.0043(70 - 25)\} \approx 48\Omega \quad \text{at Tc=70°C}$$

$$R_S|_{T=85^\circ C} \approx 40.2\{1 + 0.0043(85 - 25)\} \approx 50\Omega \quad \text{at Tc=85°C.}$$

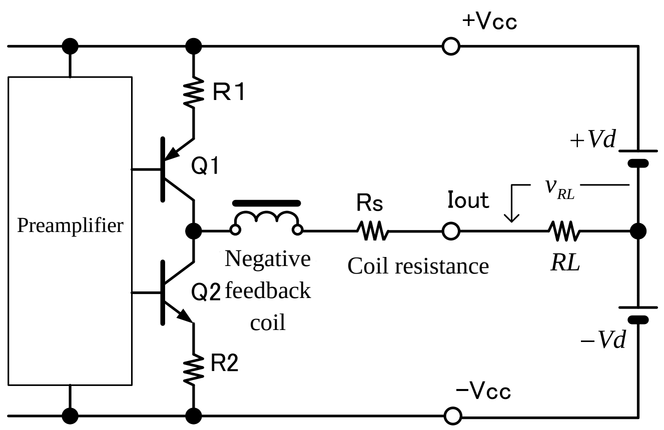


Fig. 6: Equivalent circuit of output circuit

The relation when the coil temperature is below 70°C is shown in Fig. 7 and that below 85°C is shown in Fig. 8.

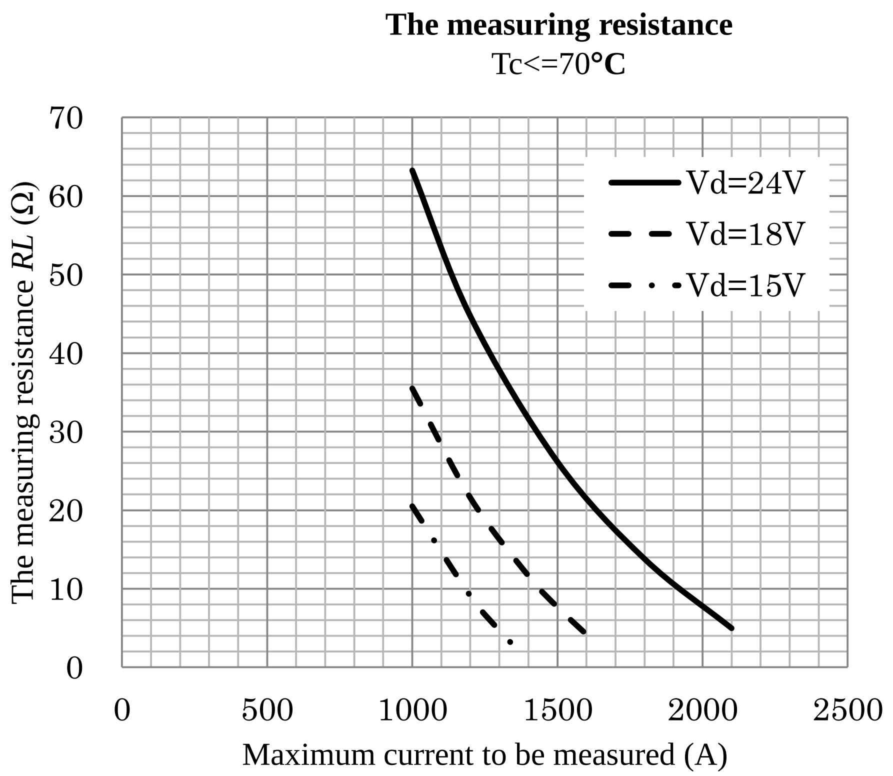


Fig. 7: The measuring resistance (when Tc=70°C or lower)

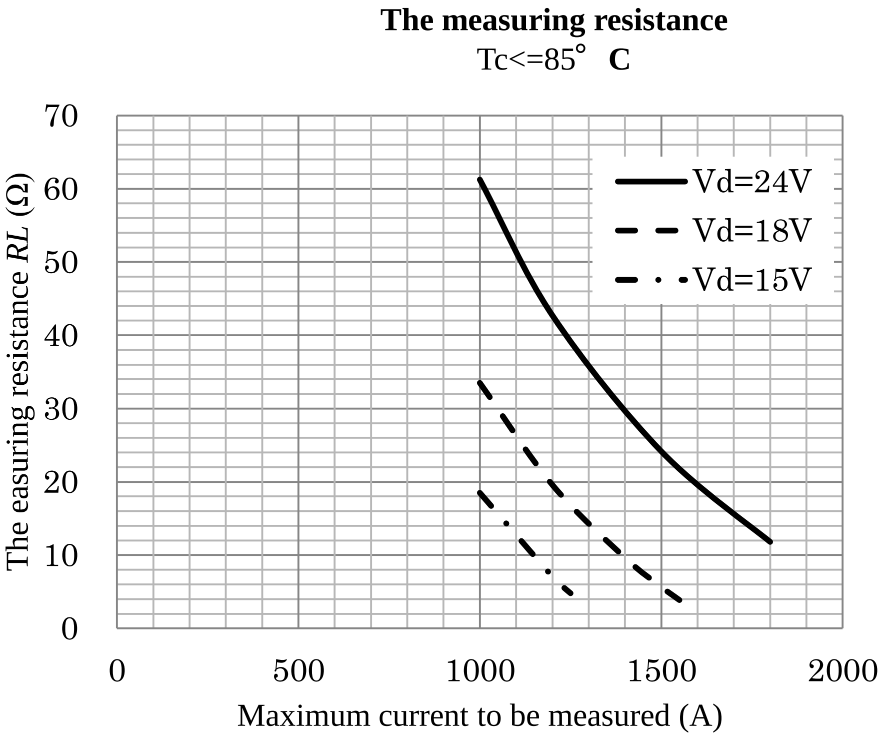


Fig. 7: The measuring resistance (when Tc=85°C or lower)

Minimum measuring resistance RL

The output current passes through each component such as the negative feedback coil and the final stage transistors Q1 and Q2 of AMP. As a result, power loss P_{INT} accompanying the output current shown in Equation 8 occurs inside the sensor.

$$P_{INT} = I_O \{Vd - RL \times I_O\} \approx Vd \times I_O - RL \times I_O^2 \quad \text{with output current } I_O. \qquad \text{Equation 8}$$

When the output current is constant, the internal loss P_{INT} associated with the output current increases as the power-supply voltage increases and the measurement resistance decreases. Therefore, the minimum measuring resistance must not be smaller than 10 Ω for the power-supply voltage of 24 V at the ambient temperature of 85°C.

Note that the magnitude of the current to be measured under continuous operation is limited to the rated current value of 1000 A because of constraints associated with internal loss.

Example of selected measuring resistance RL

Condition: Power-supply voltage Vd, plus side +24 V±10%, minus side −24 V±10%

Maximum current to be measured I_{MAX} : 1500 A

Maximum ambient temperature Ta: 85°C

Selected result: The measuring resistance $RL = 16\Omega$ from the following (1) and (2).

(1) Maximum measured resistance

Because the detection voltage becomes higher and stronger against noise as the resistance increases, it is recommended to select as high a resistance as possible.

□First, the measuring resistance becomes 24 Ω from the solid curve of the power-supply voltage of 24 V in Fig. 8.

□Next, consider a 10% reduction in the power-supply voltage.

Equation 6 gives

$$RL = Vd \times \frac{5000}{I_{MAX}} - v_{RE} \times \frac{5000}{I_{MAX}} - R_S .$$

Therefore, the influence on the allowable maximum resistance of the measuring resistance due to the decrease of the power-supply voltage of 10% becomes

$$24 \times 0.1 \times \frac{5000}{1500} = 8\Omega .$$

Therefore, the measuring resistance is reduced from 8 Ω by 24 Ω and becomes

$$24\Omega - 8\Omega = 16\Omega .$$

(2) Minimum value of measuring resistance

The internal loss of the sensor increases as the measuring resistance decreases. This internal loss gives the condition that the measuring resistance be 10 Ω or more at the ambient temperature of 85°C and at the power-supply voltage of ±24 V. Therefore, $RL = 16\Omega$ satisfies the condition of this minimum measuring resistance.

(Note) Condition for continuous measurement

The current measurable continuously is 1000 A or less. It may be as large as 2100 A for measurement within three seconds. Therefore, the measurement time is limited for 1500 A and should be evaluated for each equipment.

Offset current

The offset current Iof is the output current when the measured current is 0 A. The standard value of the offset current is 0 mA, but it can have a deviation of ±0.4 mA. When measuring the rated current, it causes an error within ±0.2%. The influence of the offset current when measuring the current twice as large as the rated current decreases to a half, and the error can be reduced to within ±0.1%. On the other hand, when half of the rated current is measured, the output current is 100 mA, and the error of the offset current ±0.4 mA increases to a value within ±0.4%.

In order to minimize the error, it is necessary to select a sensor with a rated current suitable for the measured current.

If a sensor with a rated current higher than necessary is selected, the measurement error due to the offset current increases.

Output linearity

The output linearity is the difference between a straight line approximating the input/output characteristics of the sensor and the sensor output, and the ratio (%) of the difference to the absolute value is defined as output linearity ε_L. The formula for calculating the output linearity of the measurement point J in Fig. 9 is

$$\varepsilon_L\Big|_J = \frac{\Delta_J}{I_O} \times 100 \quad (\%)\,, \qquad \text{Equation 9}$$

where

I_O : Rated output current (A),

Δ_J : Difference of sensor output current at measured current I_J from approximate linear line (A),

I_f : Rated current (A),

I_J : Measured current at measurement point J (A).

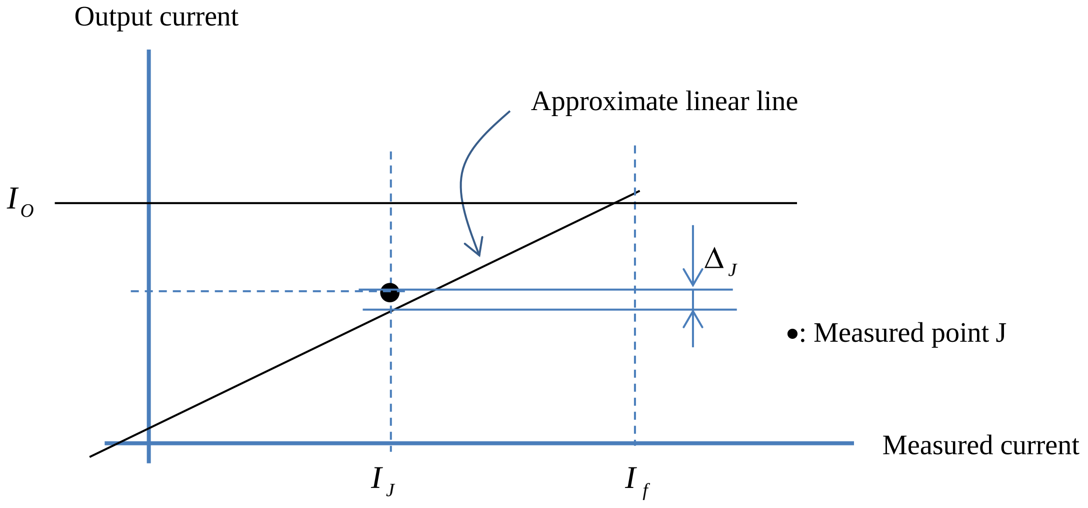


Fig. 9: Output linearity

Hysteresis error

Hysteresis error is caused by the hysteresis characteristic of the core. When the current to be measured is increased from 0 A to 3000 A and then returned to 0 A, a maximum difference of ±0.2 mA with respect to the original value arises in the output current. This difference is called hysteresis error.

When the current to be measured increases or decreases during operation, this hysteresis error occurs. The amount of error is related to the amount of change of the current to be measured. The hysteresis error becomes larger when the width of the change increases.

Overall detection accuracy $\Delta_{TOTAL}\Big|_{t1\leftrightarrow t2}^{Iin}$

For the measured current of the sensor, Iin, when the ambient temperature is between $t1$ (°C) and $t2$ (°C), the overall detection accuracy of the sensor is determined by the error given by Equation 10 where the ambient temperature is 25°C.

$$\Delta_{TOTAL}\Big|_{t1\leftarrow t2}^{Iin} = X_G + \{TcI_O \times \Delta T\} + \left(\frac{\Delta Iof + TcIof\big|_{t1\leftrightarrow t2} + I_{OH}}{I_{OUT}} \right) \times 100 \qquad \text{Equation 10}$$

where $\Delta T = t1 - 25$ or $\Delta T = t2 - 25$,

$\Delta_{TOTAL}\Big|_{t1\leftrightarrow t2}^{Iin}$: Overall detection accuracy at ambient temperature between $t1$ °C and $t2$ °C for the current to be measured, based on the ambient temperature of 25°C (%),

I_{OUT} : Output current corresponding to measured current Iin (A),

ΔIof : Deviation of offset current at 25°C (A), Table 3 No. 2,

I_{OH} : Hysteresis error (A), Table 3 No. 4,

$TcIo$: Temperature coefficient of output current (%/°C), Table 3 No. 5,

$TcIof\big|_{t1\leftrightarrow t2}$: Maximum variation of offset current deviation in the temperature range from $t1$ °C to $t2$ °C (A).

Table 3: S29S Series: List of deviations determining the accuracy of the output current　　　　Ta=25°C

No	Item	Symbol	Standard value (max)	Remarks
1	Output current accuracy	X_G	Within ±0.4%	
2	Deviation of offset current	ΔIof	Within ±0.0004 A	
3	Output linearity	ε_L	Within ±0.1%	
4	Hysteresis error	I_{OH}	Within ±0.0002 A	
5	Temperature coefficient of output current	$TcIo$	±0.01%/°C	Excluding variation of offset current
6	Temperature coefficient of offset current	$TcIof\|_{-10\leftrightarrow+70}$	±0.5 mA max	-10°C ~ +70°C
		$TcIof\|_{-40\leftrightarrow+85}$	±0.8%A max	-40°C ~ +85°C

(1) Overall detection accuracy for measurement of rated current

For the measurement of rated current I_f, Table 3 and Equation 10 give the overall detection accuracy of the rated output current Io shown in Tables 4.

Table 4: Overall detection accuracy for measurement of rated current

Ambient temperature	Accuracy Δ_{TOTAL}	Remarks
25°C	±0.7%	*
-10°C ~ +70°C	±1.4%	**
-40°C ~ +85°C	±1.8%	***

$$* \ \Delta_{TOTAL}\Big|_{25}^{I_f} = X_G + \left(\frac{\Delta Iof + I_{OH}}{I_O}\right)\times 100 \qquad (\%)$$

$$** \ \Delta_{TOTAL}\Big|_{-10\leftarrow+70}^{I_f} = X_G + \left(TcI_O \times 45\right) + \left(\frac{\Delta Iof + TcIof\big|_{-10\leftarrow+70} + I_{OH}}{I_O}\right)\times 100 \qquad (\%)$$

where $\Delta T = 45$.

$$*** \ \Delta_{TOTAL}\Big|_{-40\leftrightarrow+85}^{I_f} = X_G + \left(TcI_O \times 65\right) + \left(\frac{\Delta Iof + TcIof\big|_{-40\leftrightarrow+85} + I_{OH}}{I_O}\right)\times 100 \qquad (\%)$$

where $\Delta T = 65$.

(2) Overall detection accuracy for measurement of half of rated current $\frac{I_f}{2}$

The overall detection accuracy when measuring the current to be measured $\frac{I_f}{2}$ is given in Table 5 using items in Table 3 and Equation 10, where Io is the rated output current (A).

Table 5: Overall detection accuracy when measuring half of rated current

Ambient temperature	Accuracy Δ_{TOTAL}	Remarks
25°C	±1.2%	*
-10°C ~ +70°C	±2.2%	**
-40°C ~ +85°C	±2.4%	***

$$* \Delta_{TOTAL}\Big|_{25}^{\frac{I_f}{2}} = X_G + \varepsilon_L + \left(\frac{\Delta Iof + I_{OH}}{0.5 \times I_O}\right) \times 100 \qquad (\%)$$

$$** \Delta_{TOTAL}\Big|_{-10\leftrightarrow+70}^{\frac{I_f}{2}} = X_G + \varepsilon_L + (TcI_O \times 45) + \left(\frac{\Delta Iof + TcIof\big|_{-10\leftrightarrow+70} + I_{OH}}{0.5 \times I_O}\right) \times 100 \qquad (\%)$$

where $\Delta T = 45$.

$$*** \quad \Delta_{TOTAL}\Big|_{-40\leftrightarrow+85}^{\frac{I_f}{2}} = X_G + \varepsilon_L + (TcI_O \times 65) + \left(\frac{\Delta Iof + TcIof\big|_{-40\leftrightarrow+85} + I_{OH}}{0.5 \times I_O}\right) \times 100 \qquad (\%)$$

where $\Delta T = 65$.

Power supply

The plus or minus power supply provides an output current in addition to that consumed by the sensor. Therefore, sufficient capacity of the power supply is necessary to take care of all of them.

When operating as a current transformer, the output current is supplied from the negative feedback coil built into the sensor and passes through each of the plus and minus power supplies. Therefore, the output capacitor of the power supply must be 10 μF or more. Insert a ceramic capacitor of about 10 μF between the +Vcc terminal and GND and between the −Vcc terminal and GND, if necessary.