L07P Series

Application Manual

■ Overview

The L07P series is a "built-in coil, built-in bus bar, and onboard" current center of an open-loop type. This series comprises current sensors with two channels built into a single package. This series has variations in properties such as the power-supply voltage, as shown in Table 1.

Table 1: Variation in L07P

Variation name	Power-supply voltage	Rated current	Rated output voltage	Offset voltage Vof	Remarks
L07P□□□D15	±15V	3-30A	4.0V	0 ±0.060V	Model number ending with S indicates sulfide-resistant products.
L07P□□□D15S					
L07P□□□S05	+5V	3-30A	Vof+1.250V	Vcc/2 ± 0.040V	

(Note 1) Numbers in the positions marked by □□□ under the column "Variation name" indicate the rated current value.

Example: L07P003D15 has a power-supply voltage of ±15V and rated current of 3A.

(Note 2) Vof under the column "Rated output voltage" indicates the offset voltage.

(Note 3) Vcc under the column "Offset voltage" refers to the power-supply voltage applied to the current sensor.

■ Characteristics

- Compact and with 2 built-in channels.
- Built-in coil-type flow of the current to be measured.
- Open-loop-type circuit configuration.
- Onboard type.
- Wide range of rated current, 3A ~ 30A.

- The reference point of the output voltage has the variations shown in Table 1.
- Simple structure

Uses

- General-purpose inverter
- Motor drive
- Generator

■ Format

Variation name: L07P□□□D15

L07P 003 D 15

- Power-supply voltage 15: 15V
- Power-supply type D: Dual power supply
- Rated current 003: 3A
  - 005: 5A
  - 010: 10A
  - 015: 15A
  - 020: 20A
  - 025: 25A
  - 030: 30A
- Series name L07P

Variation name: L07P□□□D15S

L07P 003 D 15 S

- Suffix S: Sulfide resistant
- Power-supply voltage 15: 15V
- Power-supply type D: Dual power supply
- Rated current 003: 3A
  - 005: 5A
  - 010: 10A
  - 015: 15A
  - 020: 20A
  - 025: 25A
  - 030: 30A
- Series name L07P

Variation name: L07P□□□S05

L07P 003 S 05

Power-supply voltage 05: 5V

Power-supply type S: Single power supply

Rated current 003: 3A
005: 5A
010: 10A
015: 15A
020: 20A
025: 25A
030: 30A

Series name L07P

▌Block diagram (±15V Dual power-supply type)

L07P□□□D15

L07P□□□D15S

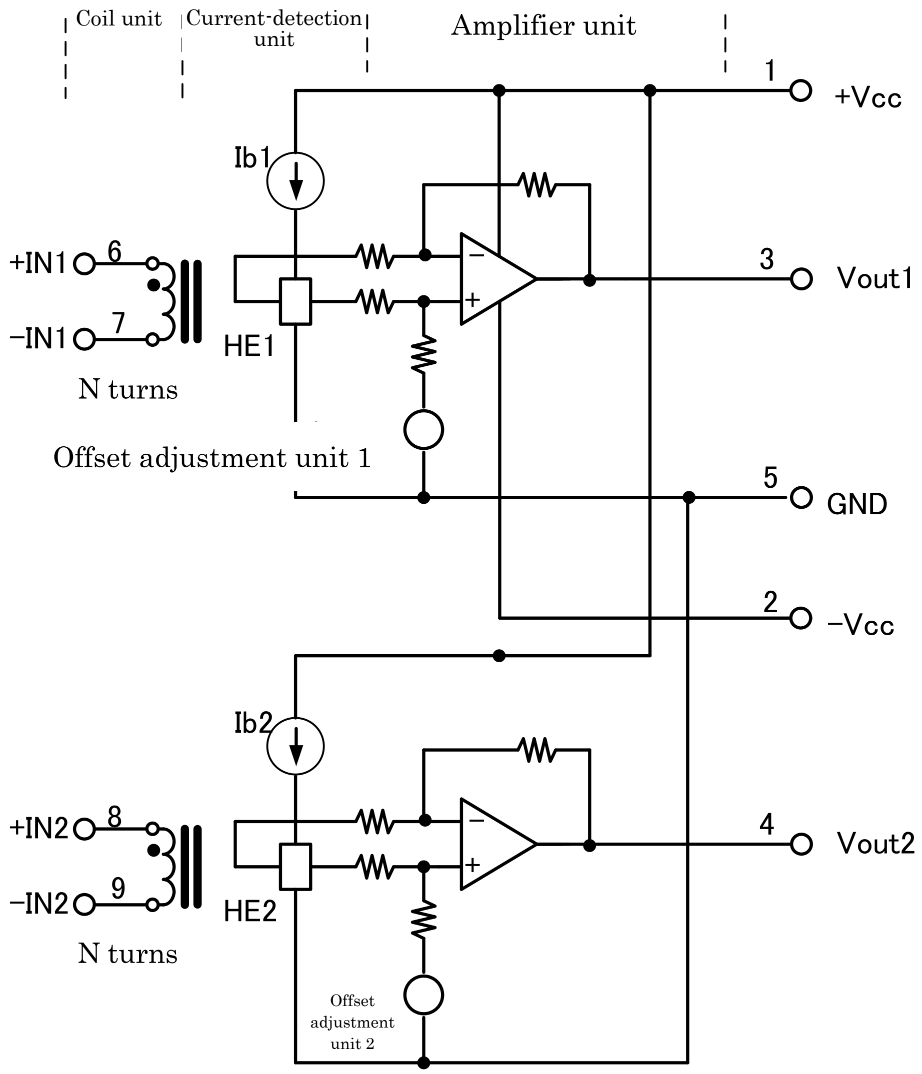


Fig. 1: L07P□□□D15　L07P□□□D15S　Internal block diagram

Table 2: L07P□□□D15　L07P□□□D15S　Description of terminals

Terminal number	Terminal name	Description	Remarks
1	+Vcc	Positive-voltage terminal of power-supply voltage Apply +15V.	
2	-Vcc	Negative-voltage terminal of power-supply voltage Apply −15V.	
3	Vout 1	Output terminal of channel 1	*
4	Vout2	Output terminal of channel 2	*
5	GND	GND terminal	
6	+IN1	When current to be measured is applied to the plus terminal (6) ⇒ (7) of the primary current (measured current) of channel 1, voltage with positive polarity is output to the output terminal (3).	
7	-IN1	The minus terminal of the primary current (measured current) of channel 1	
8	+IN2	When current to be measured is applied to the plus terminal (8) ⇒ (9) of the primary current (measured current) of channel 2, voltage with positive polarity is output to the output terminal (4).	
9	-IN2	The minus terminal of the primary current (measured current) of channel 2	

* The standard value of output voltage is

$Vout = G \times I + Vof$; $G \equiv \frac{4.0V}{If}$　If : Rated current　Vof : Offset voltage

The offset voltage is the reference voltage of the output voltage and becomes 0V in the case of a dual power supply.

L07P□□□D15　L07P□□□D15S　Description of operation

Current-detection unit

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

The generated magnetic flux is proportional to the product (N×I) of the number of windings N of the built-in coil and the measured current I. The magnetic-detection element outputs a voltage proportional to the magnetic flux, i.e., provides an output voltage proportional to the current to the next-stage amplifier.

The current-detection unit outputs the result without saturation up to current three times as large as the rated current. However, the linearity is guaranteed only up to the rated current.

Amplifier unit

This block amplifies the output voltage of the magnetic-detection element. Because the output of the magnetic-detection element is of a differential type, the amplifier unit adopts the configuration of a differential amplifier. It outputs the differential output of the magnetic-detection element as the voltage based on the GND. It adopts a circuit configuration that is negligibly affected by fluctuations in the power-supply voltage, and other in-phase signals and can ensure accurate output. The amplifier unit has the maximum output voltage limited by the power-supply voltage. Therefore, the amplifier unit may be saturated even when the current-detection unit of the preceding stage is not. When using the power-supply voltage at ±15V, it can be used without saturation up to three times the rated current.

Because the output voltage of the magnetic-detection element is determined by factors such as the rated current value and the number of windings of the built-in coil, the gain in each product is precisely adjusted in the factory.

Offset adjustment unit

The offset voltage serves as a reference of the output voltage and is given by the output voltage when the current to be measured is 0A. The standard value of the offset voltage is 0V in the case of the current sensor with the dual power supply. Possible deviation in the plus or minus direction owing to an initial deviation and temperature variations should be considered. (Please refer to the specifications table.)

The main origin of the deviation of the offset voltage from the standard value lies in the fact that the Hall element, HE, which is a magnetic sensing element, has an offset voltage. The offset voltage of the Hall element refers to the voltage output from the Hall element, which is minute but nonzero even in the absence of applied magnetic flux. A certain deviation of the offset voltage can arise in the amplifier unit instead of the Hall element. The offset adjustment unit has already been controlled in the factory in such a way that these offsets are globally canceled and fall within a predetermined range of deviation.

Coil unit

In the built-in coil, the number of windings is increased corresponding to the rated current in such a way that accurate measurement can be made even for small current.

The wire of the coil is chosen as follows: ϕ0.6 for products with rated current of 3A, ϕ0.8 for 5A, ϕ1.4 for 10A to 15A, and ϕ1.6 for 20A to 30A.

This unit generates heat due to copper loss (loss due to the coil resistance) and iron loss (loss of core) in the presence of current to be measured. Each loss varies depending on conditions such as magnitude, frequency, waveform, etc., 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.

In the case of direct current, continuous energization operation is possible up to the rated current value. For high-frequency driving, iron loss becomes serious when the frequency of the current to be measured exceeds 1 kHz. When the current contains high-frequency components other than those of the fundamental wave, the iron loss further increases. Therefore, confirmation using an actual current is necessary.

▌Block diagram (+5V Single power-supply type)

L07P□□□S05

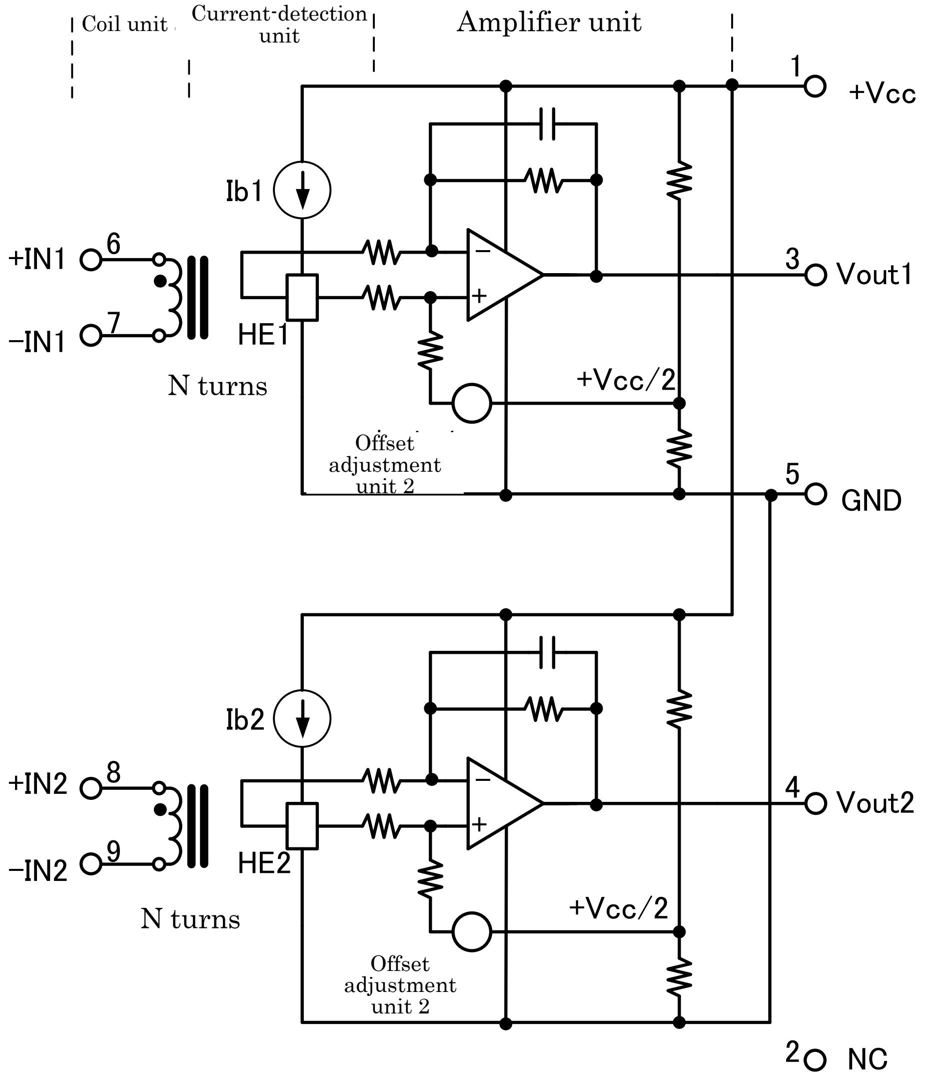


Fig. 2: L07P□□□S05 Internal block diagram

Table 3: L07P□□□S05 Description of terminals

Terminal number	Terminal name	Description	Remarks
1	Vcc	Power-supply terminal. Apply +5V	
2		NC	
3	Vout1	Output terminal of channel 1. When the primary current is applied in the direction of terminal (6) ⇒ (7), the output voltage is positive.	*
4	Vout2	Output terminal of channel 2. When the primary current is applied in the direction of terminal (8) ⇒ (9), the output voltage is positive.	● vc
5	GND	GND terminal	
6	+IN1	When current to be measured is applied to the plus terminal (6) ⇒ (7) of the primary current (measured current) of channel 1, voltage with positive polarity is output to the output terminal (3).	
7	-IN1	The minus terminal of the primary current (measured current) of channel 1	
8	+IN2	When current to be measured is applied to the plus terminal (8) ⇒ (9) of the primary current (measured current) of channel 2, voltage with positive polarity is output to the output terminal (4).	
9	-IN2	The minus terminal of the primary current (measured current) of channel 2	

* The standard value of output voltage:

$Vout = G \times I + Vof$; $G \equiv \frac{4.0V}{If}$ If :Rated current Vof : Offset voltage

The offset voltage is the reference voltage of the output voltage and becomes (Vcc/2)typ in proportion to supply voltage Vcc.

L07P□□□S05 Description of operation

Current-detection unit

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

The generated magnetic flux is proportional to the product (N×I) of the number of winding N of the built-in coil and the measured current I. The magnetic-detection element outputs a voltage proportional to the magnetic flux, i.e., provides an output voltage proportional to the current to the next-stage amplifier.

The current-detection unit outputs the result without saturation up to current 1.5 times as large as the rated current. However, the linearity is guaranteed only up to the rated current.

Amplifier unit

This block amplifies the output voltage of the magnetic-detection element. Because the output of the magnetic-detection element is of a differential type, the amplifier unit adopts the configuration of a differential amplifier. It outputs the differential output of the magnetic-detection element as the voltage based on the Vcc/2. Thereby, it adopts a circuit configuration that is negligibly affected by fluctuations in the power-supply voltage, and other in-phase signals and can ensure accurate output.

The output voltage of the magnetic-detection element is determined by factors such as the rated current value and the number of windings of the built-in coil, the gain in each product is precisely adjusted in the factory.

Offset adjustment unit

The offset voltage serves as a reference of the output voltage and is given by the output voltage when the current to be measured is 0A. The standard value of the offset voltage of this sensor is Vcc/2, which is proportional to power-supply voltage Vcc. Possible deviation in the plus or minus direction owing to an initial deviation and temperature variations should be considered. (Please refer to the specifications table.)

The main origin of the deviation of the offset voltage from the standard value lies in the fact that the Hall element, HE, which is a magnetic sensing element, has an offset voltage. The offset voltage of the Hall element refers to the voltage output from the Hall element, which is minute but nonzero even in the absence of applied magnetic flux. A certain deviation of the offset voltage can arise in the amplifier unit instead of the Hall element. The offset adjustment unit has already been controlled in the factory in such a way that these offsets are globally canceled and fall within a predetermined range of deviation.

Coil unit

In the built-in coil, the number of windings is increased corresponding to the rated current in such a way that accurate measurement can be made even for small current.

The wire of the coil is chosen as follows: ϕ0.6 for products with rated current of 3A, ϕ0.8 for 5A, ϕ1.4 for 10A to 15A, and ϕ1.6 for 20A to 30A.

This unit generates heat due to copper loss (loss due to the coil resistance) and iron loss (loss of core) in the presence of current to be measured. Each loss varies depending on conditions such as magnitude, frequency, waveform, etc., 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.

In the case of direct current, continuous energization operation is possible up to the rated current value. For high-frequency driving, iron loss becomes serious when the frequency of the current to be measured exceeds 1 kHz. When the current contains high-frequency components other than those of the fundamental wave, the iron loss further increases. Therefore, confirmation using an actual current is necessary.

Standard circuit

L07P□□□D15

L07P□□□D15S

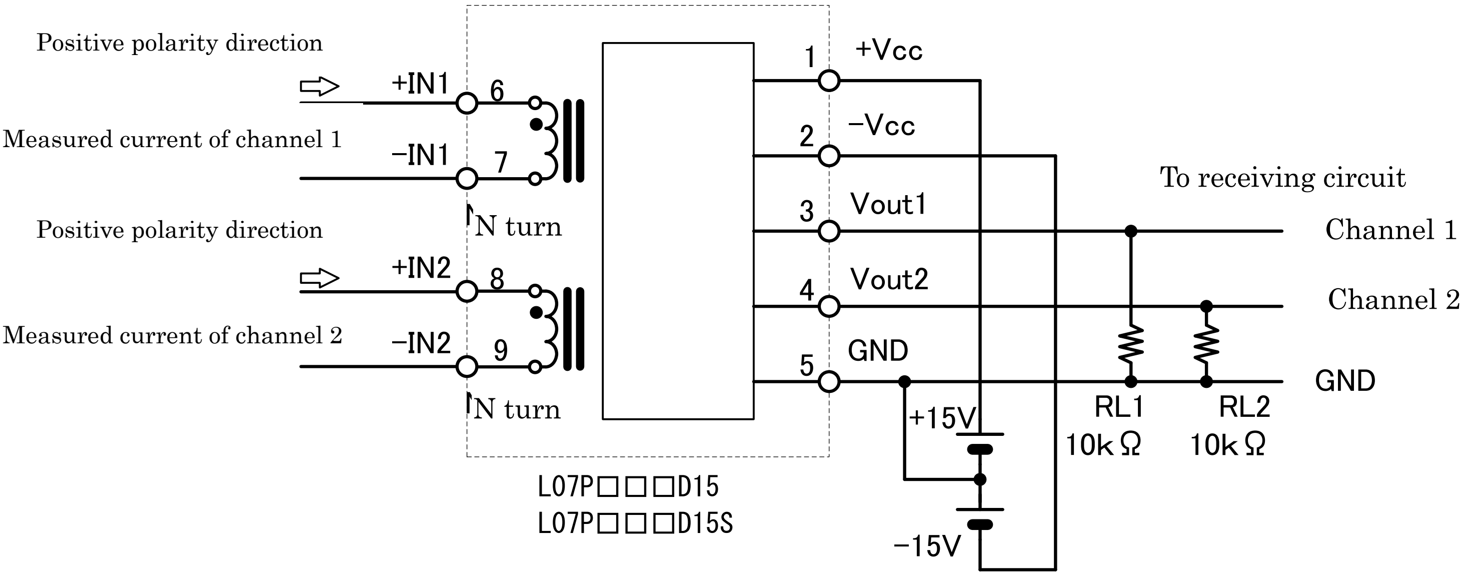


Fig. 3: L07P□□□D15　L07P□□□D15S　　Standard circuit

□Description of Fig. 3

Basic operation

This current sensor converts a measured current into a voltage. Two channels of sensors are contained in a single package. Each sensor operates independently. The output voltages Vout1 (3) and Vout2 (4) in Fig. 3 are output on the basis of the GND potential. When the current to be measured is 0, Vout (3) = 0V and Vout (4) = 0V. When current to be measured of channel 1 is in the plus direction ((6) ⇒ (7)), Vout 1 (3) has positive polarity. Similarly, Vout 2 (4) has positive polarity when the current to be measured of channel 2 is in the plus direction ((8) ⇒ (9)).

The standard value of the output voltage $Vout$ corresponding to the current Iin to be measured is the same for both channels 1 and 2, and is given by the following formula.

$$Vout = G \times Iin + Vof \quad ; \; G \equiv \frac{4.0V}{If}$$

If : Rated current　Vo : Offset voltage　Standard value is $0V$

RL1 = RL2 = 10 kΩ in Fig. 3 is the equivalent resistance of the receiving circuit of the current sensor outputs Vout1 (3) and Vout2 (4). The standard value of resistance RL is 10 kΩ.

Effect of offset voltage

The offset voltage Vof is 0 ± 60mV at maximum under the condition of Ta = 25°C. An error within ±1.5% occurs when measuring the rated current. When measured current is three times the rated current, the influence of the offset voltage decreases to 1/3 and the error is compressed within ±0.5%. When measured current is half the rated current, the error in the offset voltage of ±60mV is within ±3%, because the output voltage is 2.0V.

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 higher rated current than necessary is selected, the measurement error due to the offset voltage increases. In selecting the rated current, it is necessary to consider the capability of covering the peak value of the measured current, heat generated by the coil and the core, etc., as well as the above conditions.

Standard Circuit

L07P□□□S05

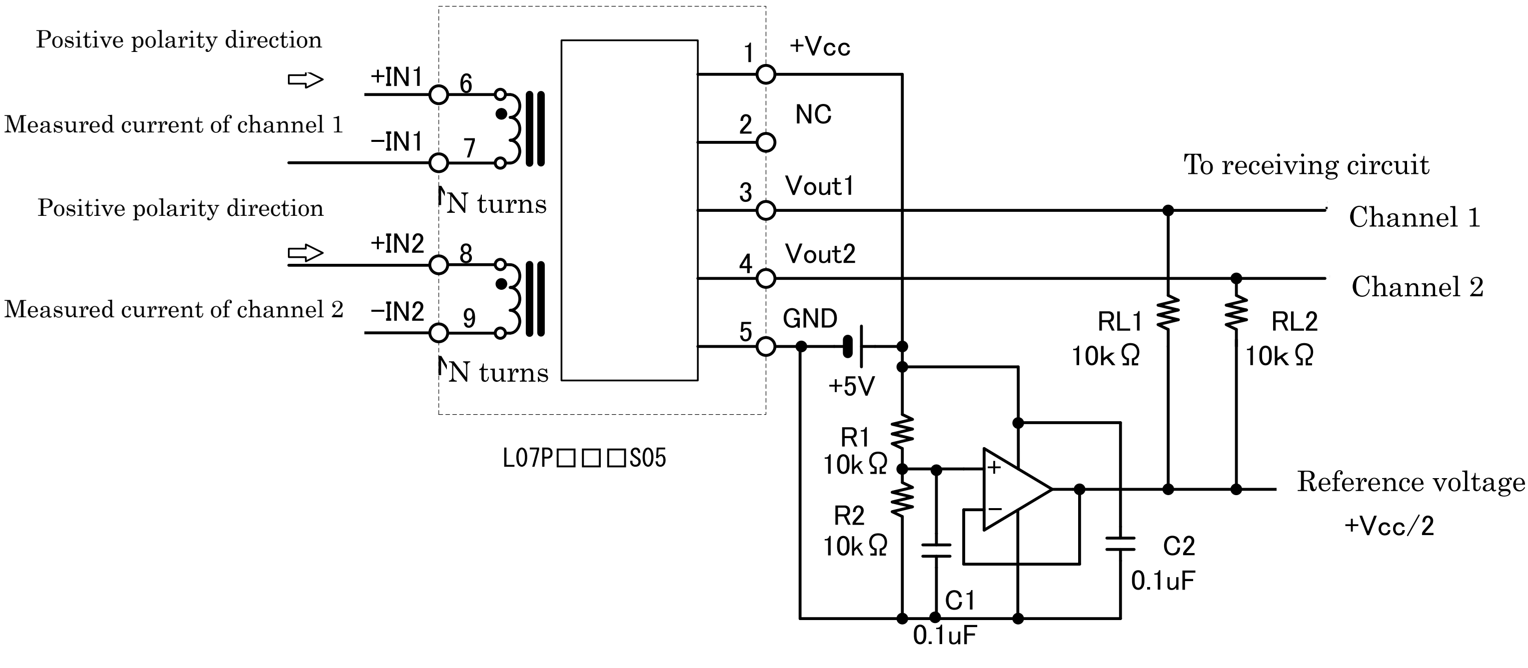


Fig. 4: L07P□□□S05 Standard circuit

□Description of Fig. 4

Basic operation

This current sensor converts a measured current into a voltage. The output voltages Vout1 (3) and Vout2 (4) in Fig. 4 are output on the basis of Vcc/2 potential. When the current to be measured in channel 1 is 0, Vout1 (3) = Vcc/2. When the current to be measured is in the plus direction ((6) ⇒ (7)), Vout1 (3) becomes (Vcc/2) + (voltage converted from the measured current). When the current to be measured is in the minus direction ((7) ⇒(6)), Vout1 (3) becomes (Vcc/2) – (voltage converted from the measured current). The same is applicable to channel 2.

The standard value of the output voltage $Vout$ corresponding to the current Iin to be measured is expressed by the following equation.

$$Vout = G \times Iin + Vof \quad ; \; G \equiv \frac{1.25V}{If}$$

If : Rated current Vo ; Offset voltage Standard value is $\frac{Vc}{2}$

RL = 10 kΩ in Fig. 4 is the equivalent resistance of the receiving circuit of the current sensor output Vout (4). Connect between Vout terminal (4) and reference potential (Vcc/2).

Effect of offset voltage

The offset voltage Vof is (Vcc/2) ± 40mV at maximum under the condition of Ta = 25°C. An error within ±3.2% occurs when the rated current is measured. The effect of the offset voltage when measuring a current 1.5 times the rated current decreases to ±2.1%. When a current of half the rated current is measured, the output voltage is 0.625V and the error of the offset voltage of ±40mV is within ±6.4%.

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 higher rated current than necessary is selected, the measurement error due to the offset voltage increases. In selecting the rated current, it is necessary to consider the capability of covering the peak value of the measured current, heat generated by the coil and the core, etc., as well as the above conditions.

Detection accuracy

The detection accuracy of the current sensor includes the error shown in Table 5.

Table 5: L07P□□□S05 output voltage accuracy Ta = 25°C RL = 10kΩ Vcc = +5V

No	Item	Symbol	Standard value (max)	Remarks
1	Deviation of rated output voltage	ΔVo	Within ±0.040V	
2	Deviation of offset voltage	ΔVof	Within ±0.040V	
3	Output linearity	εL	Within ±1%	
4	Hysteresis error	V_{CH}	Within ±15mV	
5	Temperature variation of output voltage	TcVo	±2mV/°C	
6	Temperature variation of offset voltage	TcVof	±2mV/°C	

The total deviation (%) at the rated current, obtained by summing the deviations of No. 1 to No. 6 in Table 5, is given by the following formula.

$$\Delta_{TOTAL} = 100 \times \left\{ \frac{\Delta V_O}{V_O} + \frac{\Delta Vof}{V_O} + \frac{\varepsilon_L}{100} + \frac{V_{CH}}{V_O} + \frac{T_C V_O}{V_O}\left(|Ta-25|_{MAX}\right) + \frac{T_C Vof}{V_O}\left(|Ta-25|_{MAX}\right) \right\}$$

Δ_{TOTAL}: Overall deviation at the rated current value (%)

V_O : Rated output voltage minus offset voltage (V_O = 1.25 V)

ΔV_O: Deviation of rated output voltage (V)

ΔVof : Deviation of offset voltage (V)

ε_L: Output linearity (%)

V_{CH}: Hysteresis error (V)

$T_C V_O$: Temperature variation of output voltage (%/°C)

$T_C Vof$: Temperature variation of offset voltage (V/°C)

$|Ta-25|$: Maximum difference between ambient temperature and 25°C (deg)

* When the ambient temperature is 25°C, the total deviation of the rated current is within ±8.6%.
* When the ambient temperature is between −10°C and +60°C, the total deviation of the rated current is within ±19.8%.

▌Application Circuit: Conversion circuit with reference voltage of 2.5V

L07P□□□D15

L07P□□□D15S

– Can be converted to CPU reference voltage (2.5 V) with accuracy being maintained. –

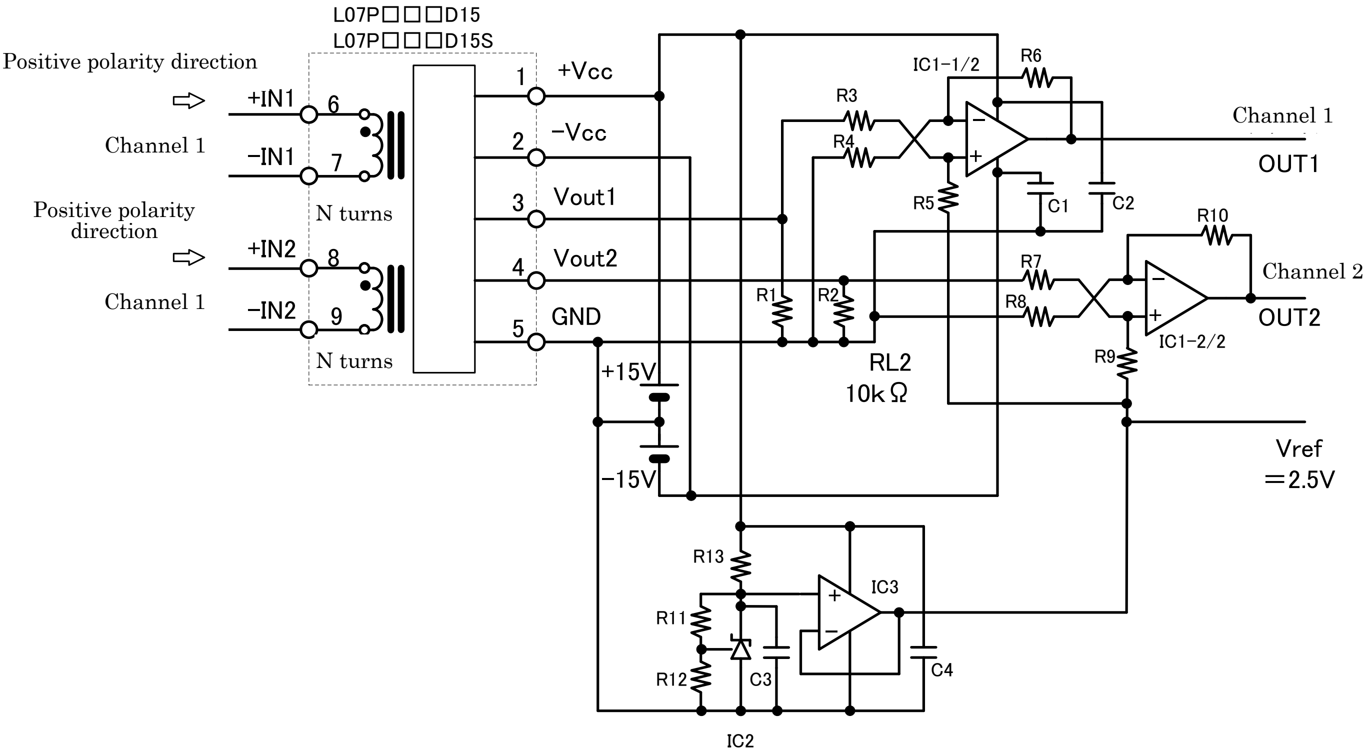


Fig. 5: L07P□□□D15 L07P□□□D15S Conversion circuit with reference voltage of 2.5V

Table 6: Conversion circuit with reference voltage of 2.5V

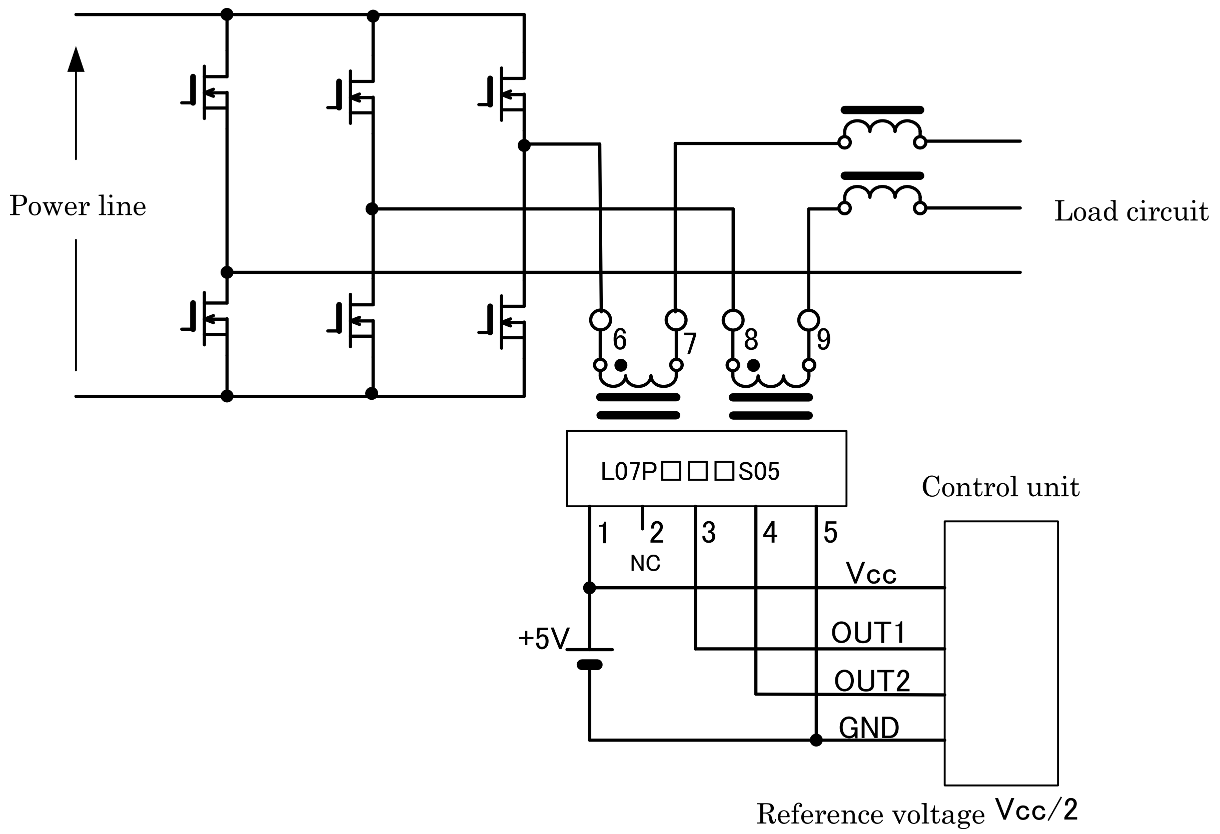
Symbol	Product name	Model number / Rating	Manufacturer	Remarks
C1, C2, C3, C4	Ceramic capacitor	/0.1uF		
IC1, IC3	Integrated circuit	RC4580IPWR	TI	
IC2	〃	TL431	TI	
R1, R2	Fixed resistor	33kΩ		
R3, R4, R7, R8	〃	14.08kΩ		
R5, R6, R9, 10	〃	2.2kΩ		
R11, R12	〃	4.7kΩ		
R13	〃	6.2kΩ		

The output voltage *Vout* corresponding to the current *Iin* to be measured, as shown in Fig. 5, is expressed by the following equation.

$$Vout = G \times Iin + Vof \quad ; \; G \equiv \frac{0.625V}{If} \qquad If: \text{Rated current} \qquad Vof: \text{Offset voltage} \quad \text{Standard value is} \quad 2.5V$$

Application circuit: Inverter current-detection circuit

L07P□□□S05



The output voltage $Vout$ corresponding to the current Iin to be measured is given by the following equation.

$$Vout = G \times Iin + Vof \quad ; \; G \equiv \frac{1.25}{If} \qquad If: \text{Rated current} \qquad Vof: \text{Offset voltage} \quad \text{Standard value is} \quad \frac{Vc}{2}$$

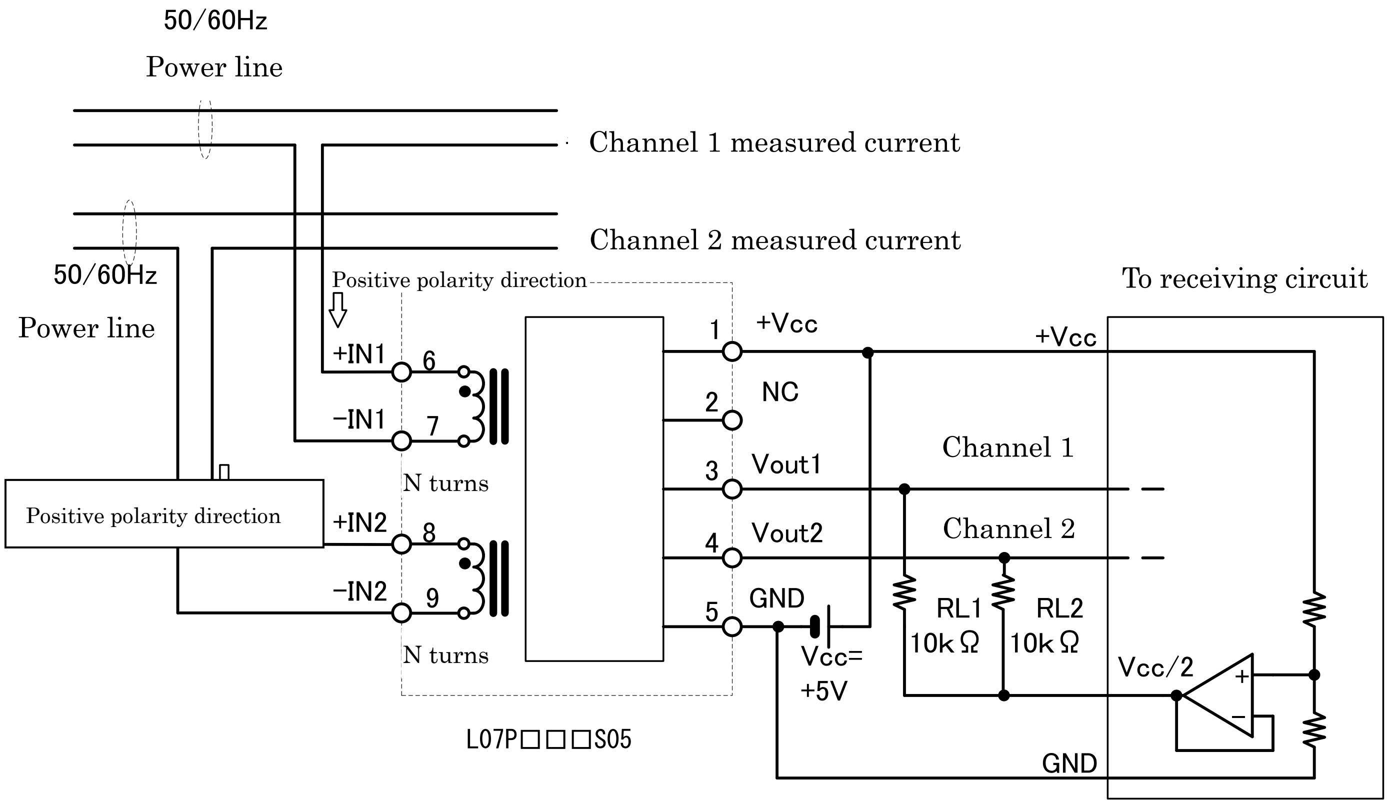
Fig. 6: L07P□□□S05 Inverter current-detection circuit

▌Application circuit: Current-detection circuit for 50Hz

L07P□□□S05

– Miniaturization possible compared with current transformer –

The L07P□□□S05 sensor can be directly connected to a receiving circuit by making the power-supply line the same as the receiving circuit. The reference voltage of the receiving circuit must be Vcc/2 for the power-supply voltage Vcc.



The output voltage *Vout* corresponding to the current *Iin* to be measured is given by the following equation.

$$Vout = G \times Iin + Vof \quad ; \; G \equiv \frac{1.25}{If}$$

If : Rated current $\quad Vof$: Offset voltage Standard value is $\frac{Vc}{2}$

Fig. 7: L07P□□□S05 Current-detection circuit for 50Hz/60Hz