Fluxgate-Based Residual Current Sensor, FG-R01 Series

Overview

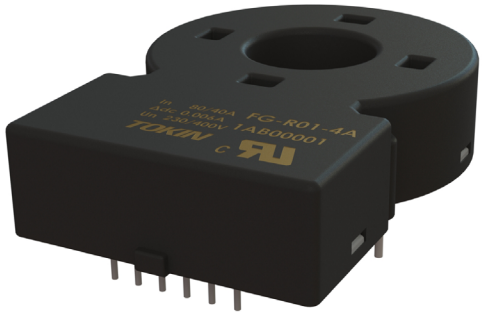
The FG-R01 series sensor is a high-sensitivity AC and DC leakage current sensor with individual open drain alarms and an analog output for leakage current indication. In addition, its integrated test coil can be initiated by a test input to perform a functional alarm test. The UL 2231 version (*4GA) contains 2 AC alarms to comply with CCID5 and CCID20.

Applications

Typical applications include residual current sensor for In-Cable Control and Protection Devices (IC-CPD) or Wallbox.

Benefits

- Open-loop, fluxgate-based current sensor
- PCB mounting
- Digital output of fault detection
- Conforms to IEC 62752:2016/A1:2018 (FG-R01-4A and FG-R01-4BA)
- Conforms to IEC 62955:2018[1] (FG-R01-4A and FG-R01-4BA)
- Conforms to UL 2231-2 CCID20 & CCID5 (FG-R01-4GA)
- RoHS compliant
- 3,000 A surge current capability
- Composed of AEC-Q certified parts
- Compliant with ASIL_B for Safety Element out of Context(SEooC)



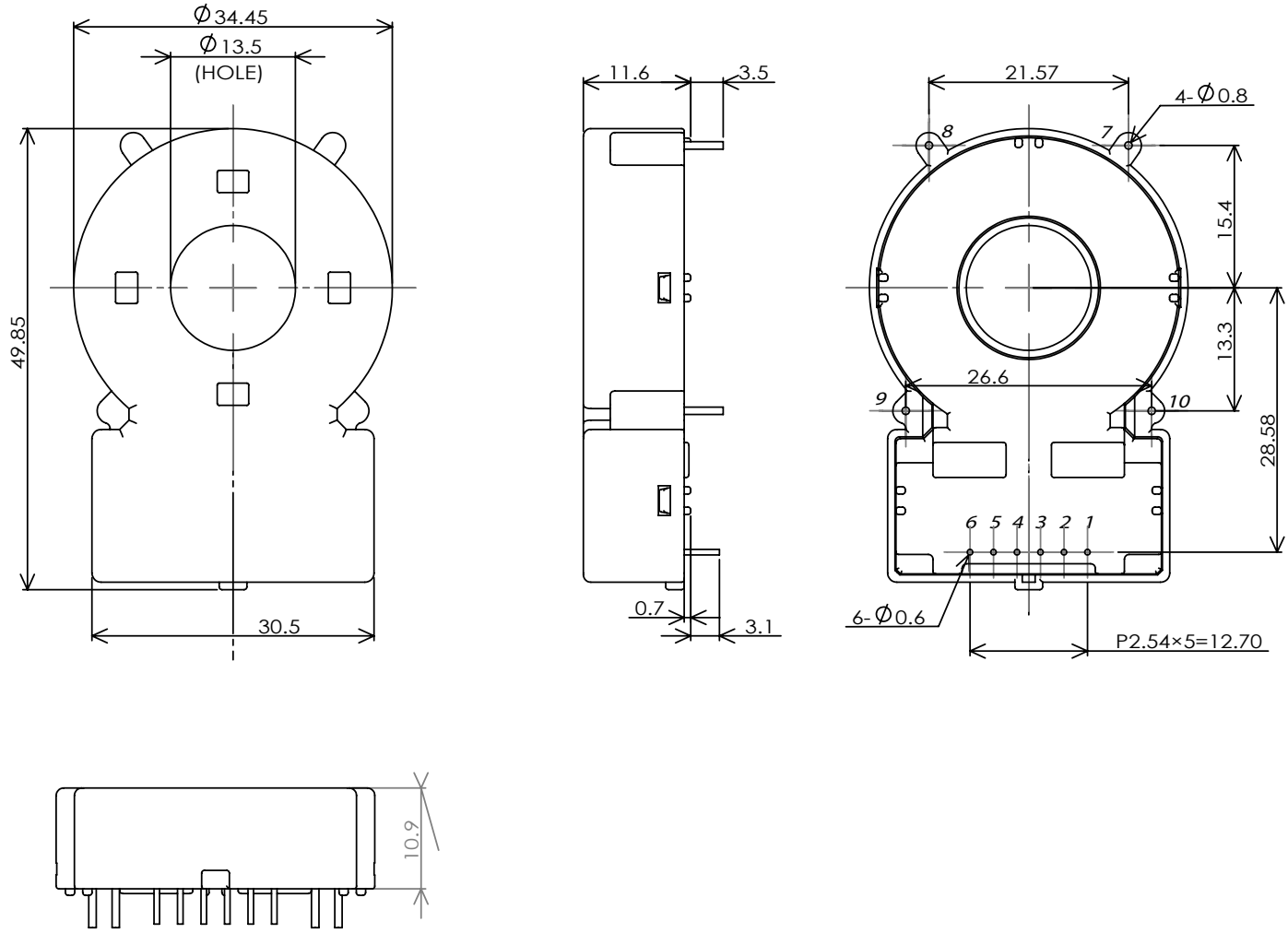
Ordering Information

FG-	R01-	4A
Series	Shape	Current Detection Standards
FG	R01 = Horizontal without busbar	4A = IEC 62752:2016/A1:2018 and UL 2231-2, IEC 62955:2018[1] 4BA = IEC 62752:2016/A1:2018, IEC 62955:2018[1] 4GA = UL 2231-2

[1] *Conditional and dependant on the circuit/system designed as explained in the section Recommended Circuit of this datasheet.*

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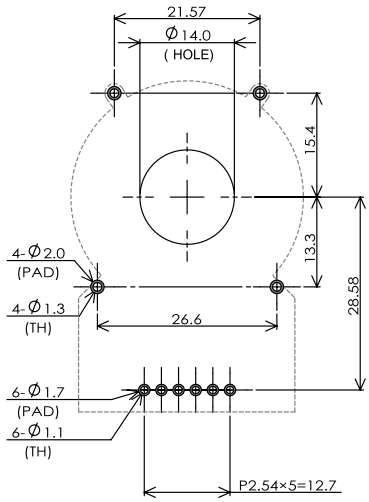
Dimensions in mm



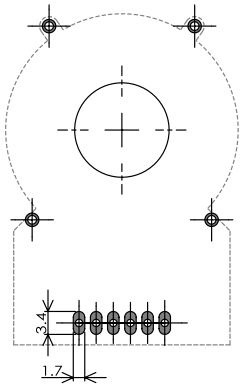
Pin Number	Symbol	
	FG-R01-4A, FG-R01-4BA	FG-R01-4GA
1	VDD	VDD
2	GND	GND
3	AOUT	AOUT
4	DC Fault	AC Fault(CCID5)
5	AC Fault	AC Fault(CCID20)
6	TEST	TEST
7-10	Dummy	Dummy

PCB Footprint - Top View

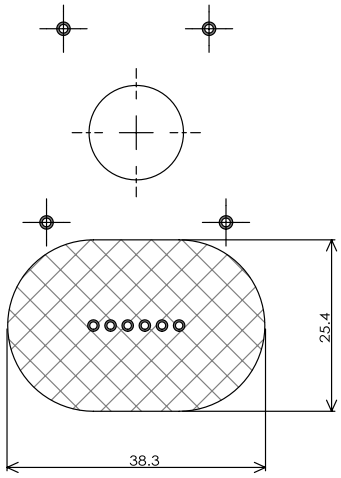
Component Side



Solder Side



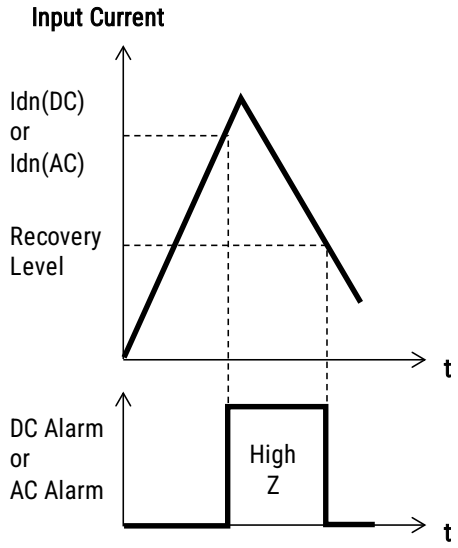
Restricted Areas



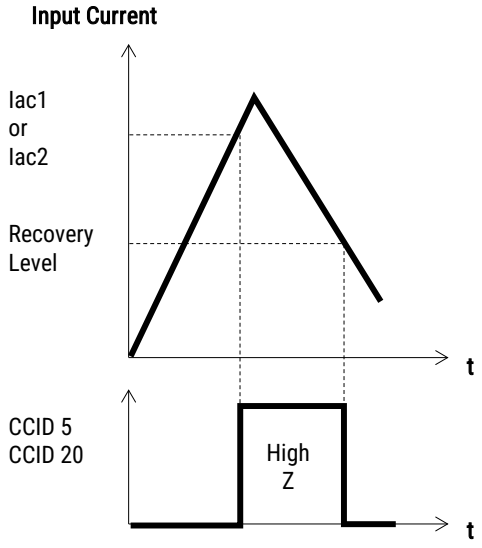
Output Characteristics

Switching Operation

FG-R01-4A, FG-R01-4BA



FG-R01-4GA

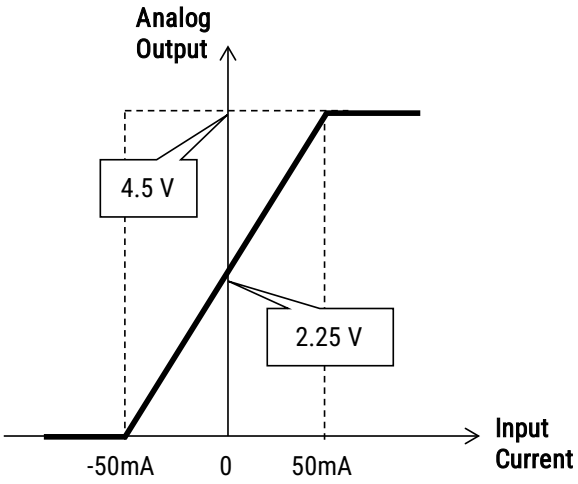


FG-R01-4A, FG-R01-4BA
When the residual current exceeds the threshold level (Idn(DC) or Idn(AC)), PIN 4 (DC Alarm) or PIN 5 (AC Alarm) will change from low level to high impedance. Each output goes back from high impedance to low level when residual current falls below recovery level.

FG-R01-4GA
When the residual current exceeds the threshold level (Iac1 or Iac2), PIN 4(CCID5) or PIN 5(CCID20) will change from low level(GND) to high impedance. Each output recovers from high impedance to low level with residual currents decrease below recovery level.

Output Characteristics (cont.)

PIN 3 Analog Output – DC Characteristics



Output State

FG-R01-4A

DC Alarm	AC Alarm	State
GND	GND	Normal Condition
High Impedance	GND	DC Detection Current ≥ 6 mA
GND	High Impedance	AC Detection Current ≥ 20 mA
High Impedance	High Impedance	DC Detection Current ≥ 6 mA and AC Detection Current ≥ 20 mA

Temperature of primary wire should not exceed 105°C.
The rise time of the supply voltage is 50 us to 100 ms.

FG-R01-4BA

DC Alarm	AC Alarm	State
GND	GND	Normal Condition
High Impedance	GND	DC Detection Current ≥ 6 mA
GND	High Impedance	AC Detection Current ≥ 30 mA
High Impedance	High Impedance	DC Detection Current > 6 mA and AC Detection Current ≥ 30 mA

Temperature of primary wire should not exceed 105°C.
The rise time of the supply voltage is 50 us to 100 ms.

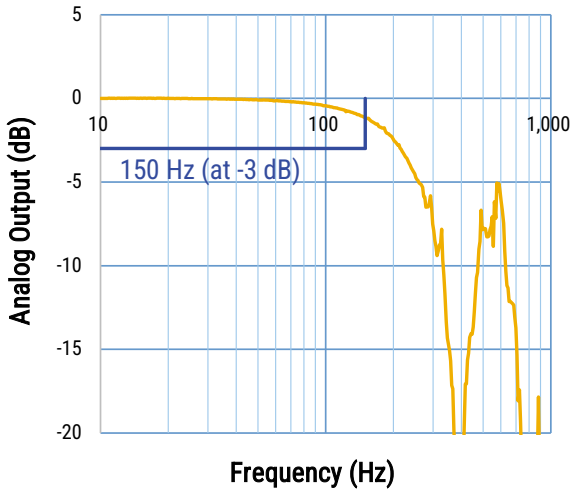
FG-R01-4GA

CCID 5	CCID 20	State
GND	GND	Normal Condition
High Impedance	GND	Ip > Iac1
High Impedance	High Impedance	Ip > Iac2

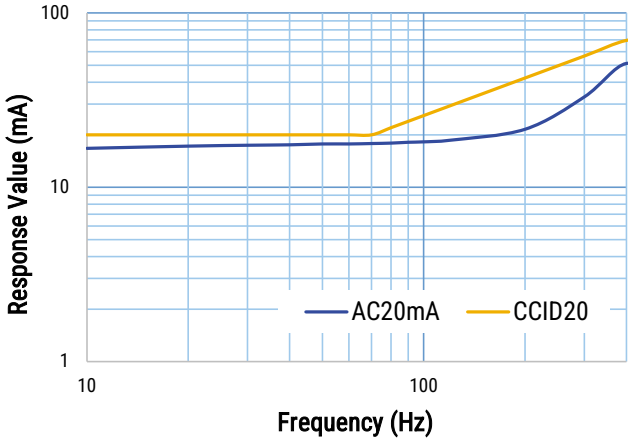
Temperature of primary wire should not exceed 105°C.
The rise time of the supply voltage is 50 us to 100 ms.

Output Characteristics (cont.)

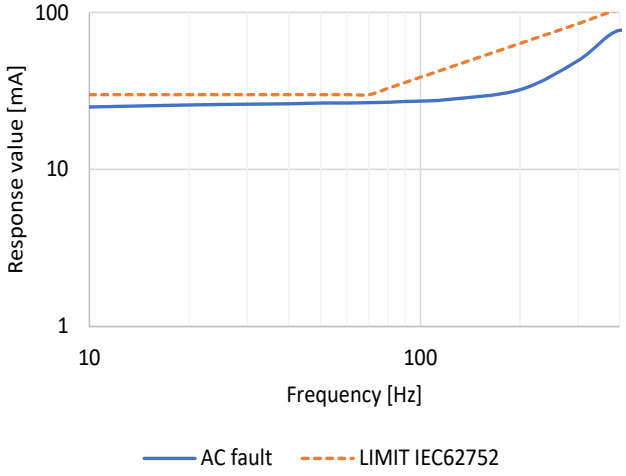
Frequency Characteristics of Analog Output



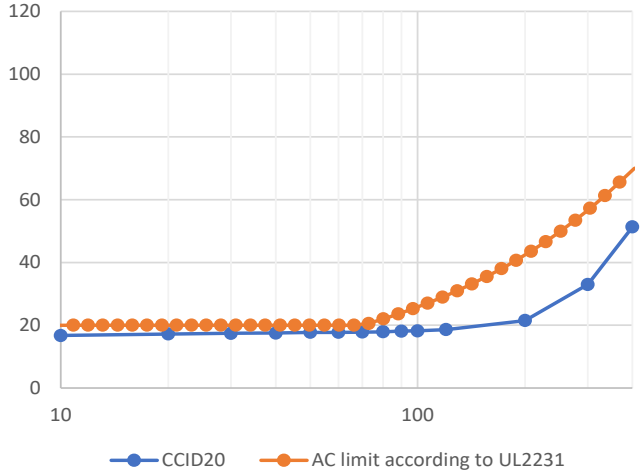
Frequency Characteristics of Response Value (FG-R01-4A)



Frequency Characteristics of Response Value (FG-R01-4BA)

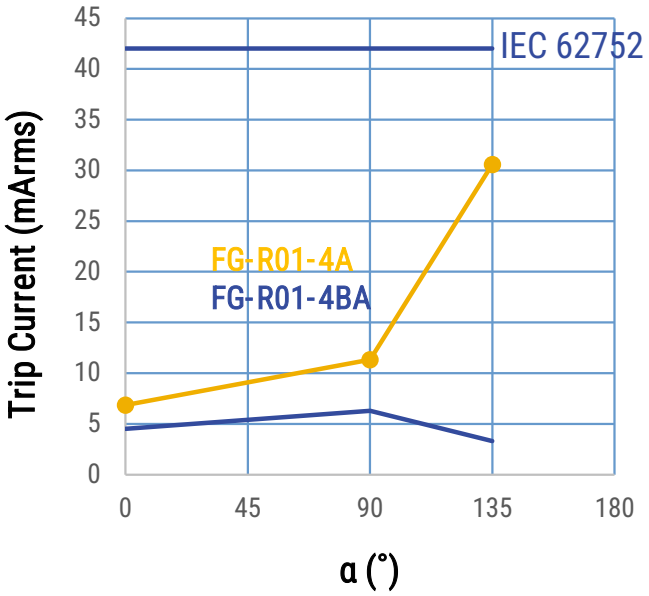


Frequency Characteristics of Response Value (FG-R01-4GA)

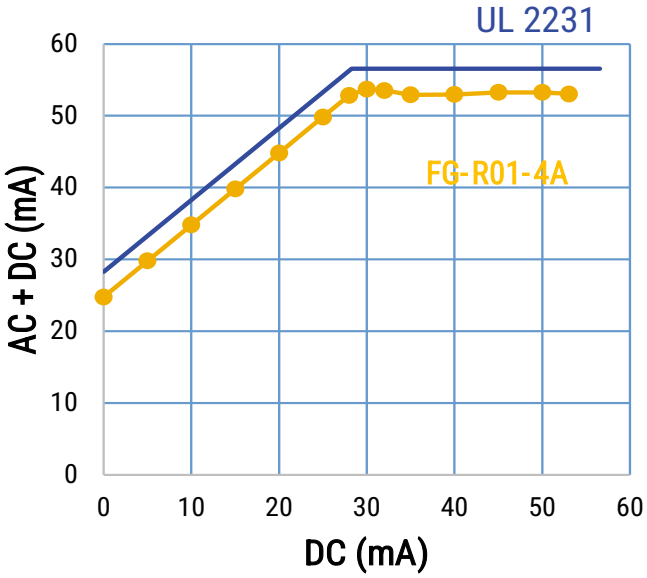


Output Characteristics (cont.)

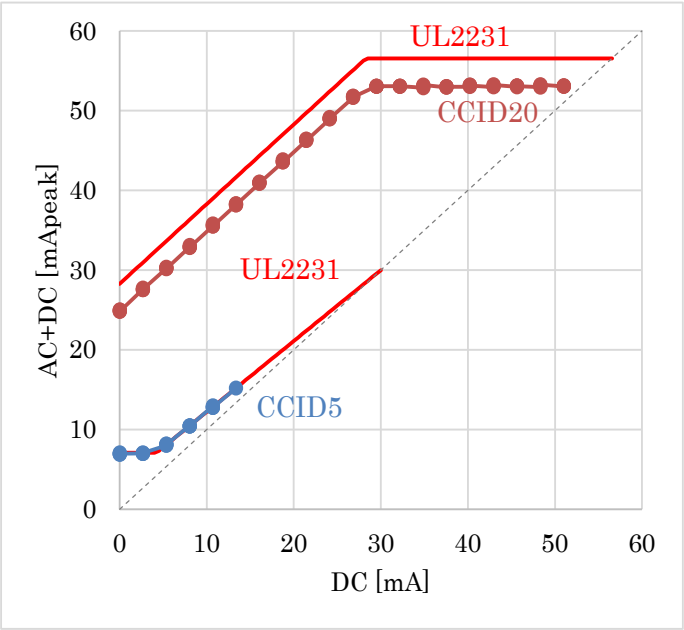
Trip Current of Pulsating DC at Phase 0°, 90°, 180°



Trip Current of AC + DC



Trip Current of AC + DC (FG-R01-4GA)



Above data are not guaranteed values, for reference only.

Environmental Compliance

FG sensors are RoHS compliant.

Specifications

Item	Performance Characteristics
Primary Rated Voltage (Phase/Line)	230/400 V
Primary Nominal Current	80/40 A Maximum (1 phase/3 phase)
Supply Voltage Range	4.75 – 5.25 V (5 V typical)
Maximum Input Voltage of Digital Output	Supply Voltage + 0.3 V
Input Voltage Range of TEST (LOW)	0.0 – 0.6 V
Input Voltage Range of TEST (HIGH)	2.5 V - Supply Voltage
Maximum Sink Current of Digital Output	10 mA
Current Consumption	13 mA (at measurement 0 mA)
Operating Temperature Range	−40°C to +105°C
Storage Temperature Range	−40°C to +105°C

Tests

ESD Test

DC Detection Current within specifications as per Table 1 – Ratings & Part Number Reference after ESD test.

Parameter	Result
Electrostatic Discharge Voltage Human-Body Model (HBM) R = 1,500 Ω, C = 100 pF, U = ±2,000 V	Passed
Electrostatic Discharge Voltage Charged-Device Model (CDM) U = ±800 V	Passed

Tests (cont.)

EMC Test

DC Alarm and AC Alarm do not malfunction during noise stimulation.

Parameter	Conditions	Result
IEC 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity	20 V/m, 80 MHz – 1 GHz 80% AM 1 kHz	Passed
ISO 11452-2 (ALSE) Electrical disturbances from narrowband radiated electromagnetic energy	50 V/m 200 MHz – 800 MHz 80% AM 1 kHz, 800 MHz – 2 GHz PM	Passed
ISO 11452-4 (BCI) Electrical disturbances from narrowband radiated electromagnetic energy	100 mA 20 MHz – 200 MHz 80% AM 1 kHz	Passed
IEC 62955 § 9.18.2 Surge current immunity test	Peak 3,000 A Virtual front time 8 µs Virtual time to half value 20 µs	Passed

Dielectric Strength

Parameter	Conditions	Values
$U_{W, prim-sec}$	Impulse (1.2 µs/50 µs), PIN 1-6 vs insulated primary wire, 5 pulse -> polarity +, 5 pulse -> polarity -	5,500 V_{rms}
U_d	Test voltage, 60 seconds PIN 1-6 vs insulated primary wire	1,500 V_{rms}
$U_{PDx1.5}$	Partial discharge voltage, PIN 1-6 vs insulated primary wire * acc. to table 24	1,200 V_{rms}
$U_{PDx1.875}$	Partial discharge voltage, PIN 1-6 vs insulated primary wire * acc. to table 24	1,500 V_{rms}

** IEC 61800-5-1:2007*

Table 1 – Ratings & Part Number Reference

Part Number	Measurement Range (mA)	DC Detection Current[1] (mA)	AC Detection Current[1] [2] (mArms)	DC Alarm Response Time (ms)	AC Alarm Response Time (ms)
FG-R01-4A	−50 - +50	4.5 typical 3 minimum 6 maximum	17.5 typical 15 minimum 20 maximum (at 55 Hz)	280 typical, 1,000 maximum (at measurement = 6 mA) 24 typical, 250 maximum (at measurement = 60 mA) 6 typical, 15 maximum (at measurement = 300 mA)	60 typical, 250 maximum (at measurement = 30 mArms) 20 typical, 100 maximum (at measurement = 60 mArms) 8 typical, 20 maximum (at measurement = 150 mArms) 7 typical, 10 maximum (at measurement = 264 mArms) 7 typical, 10 maximum (at measurement > 5 Arms)
FG-R01-4BA	−50 - +50		27.5 typical 25 minimum 30 maximum (at 55 Hz)		60 typical, 250 maximum (at measurement = 30 mArms) 20 typical, 100 maximum (at measurement = 60 mArms) 8 typical, 15 maximum (at measurement = 150 mArms) 7 typical, 10 maximum (at measurement > 5 Arms)

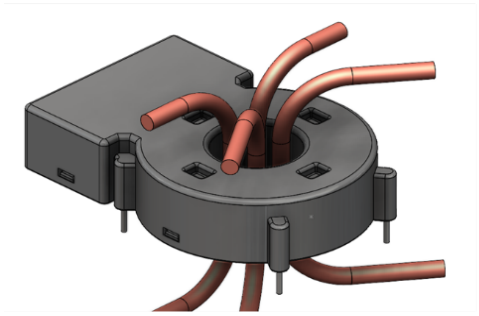
Part Number	Measurement Range (mA)	CCID5 Detection Current[1] (mA) Iac1	CCID20 Detection Current[1] (mArms) Iac2	CCID5 Detection Response Time (ms)	CCID20 Detection Response Time (ms)
FG-R01-4GA	−50 - +50	5 typical 4 minimum 6 maximum (at 60 Hz)	15 typical 17.5 minimum 20 maximum (at 60 Hz)	200 maximum (at measurement = 6 mA) 100 maximum (at measurement = 20 mA) 20 maximum (at measurement = 150 mA) 10 maximum (at measurement = 264 mA)	200 maximum (at measurement = 20 mArms) 20 maximum (at measurement = 150 mArms) 10 maximum (at measurement = 264 mArms)

[1] Recovery level = detection current/2.

[2] Frequency characteristic of AC detection current = −1% typical, −2% minimum at 45 Hz/55 Hz and +1% typical, +2% maximum at 65 Hz/55 Hz.

Part Number	PIN 3 AOUT Sensitivity (V/A)	PIN 3 AOUT Offset Voltage (V)	PIN 3 AOUT Frequency Range (Hz)	Hole Diameter (mm)	Weight (g)
FG-R01-4A	40 typical	2.25 typical	150 maximum (at −3 dB)	Φ 13.5	20
FG-R01-4BA					
FG-R01-4GA					

Recommended Wire Configuration for Bare Wire



**1 Please consider clearance between primary and primary.*

Soldering Process

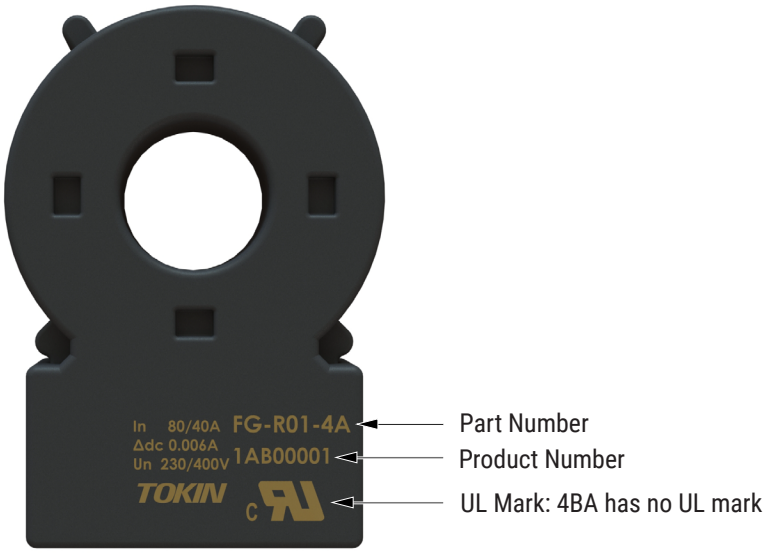
Wave Soldering	Preheating temperature	100 – 140°C
	Preheating time	within 40 seconds
	Heating temperature	260°C
	Heating time	within 10 seconds

Packaging

Type	Packaging Type	Pieces Per Box
FG	Tray	300

The product is packed in antistatic trays.

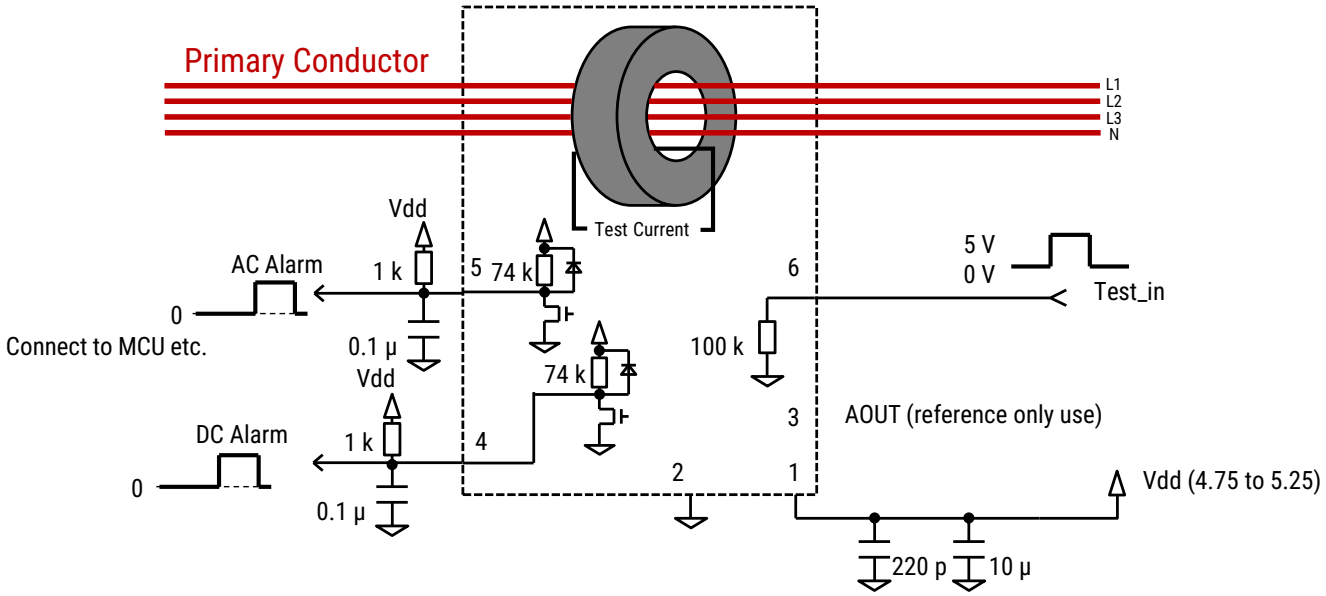
Marking



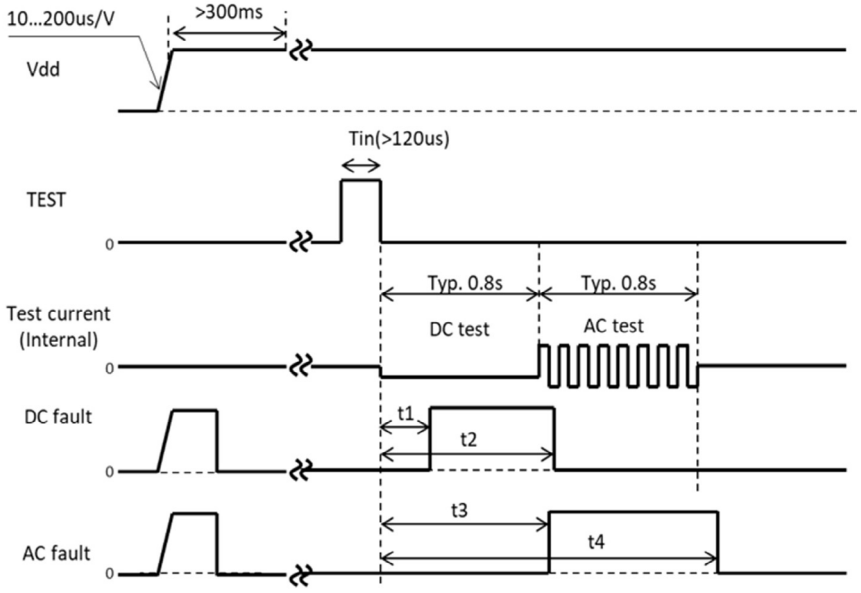
Lot Code	
1st digit = Manufacturing Line Number	1 : Line No.1 2 : Line No.2
2nd digit = Year	1 = 2021 2 = 2022 3 = 2023 A = 2030 B = 2031
3rd digit = Month of the Year	1 = January 2 = February to A = October B = November C = December
4th and 5th digit = Day of the Month	01 = 1st to 31 = 31st
6th to 10th digit = Serial Number	00001 00002 etc

Self-Test Operation

FG-R01-4A
FG-R01-4BA



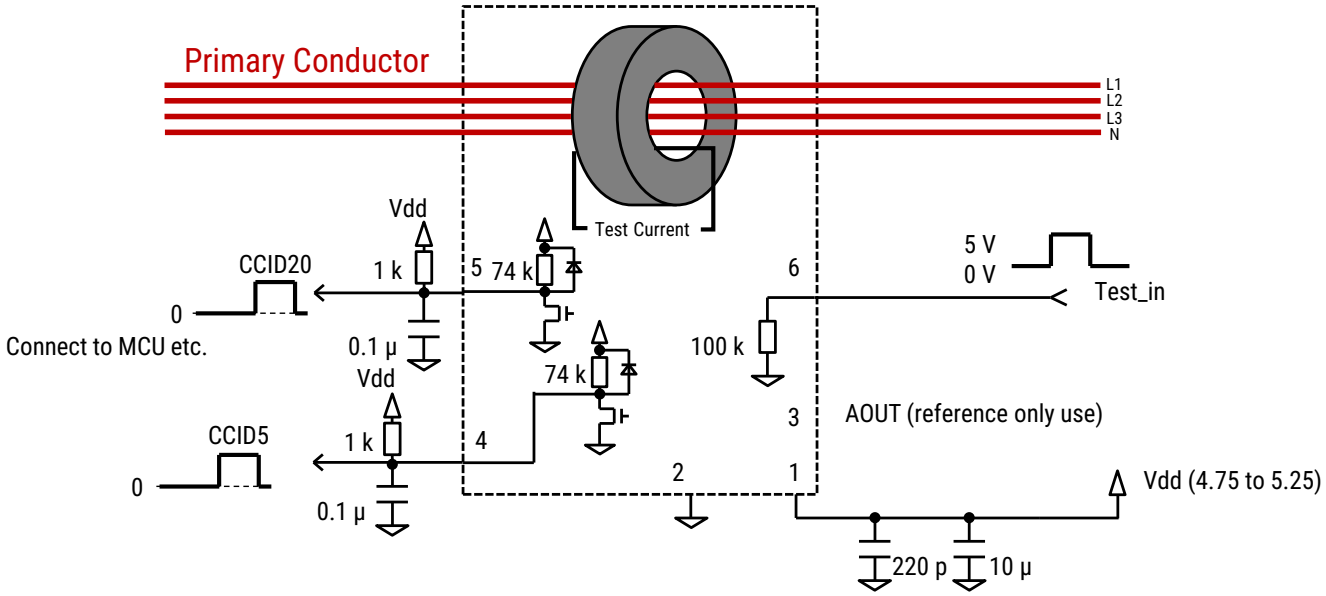
Time Chart



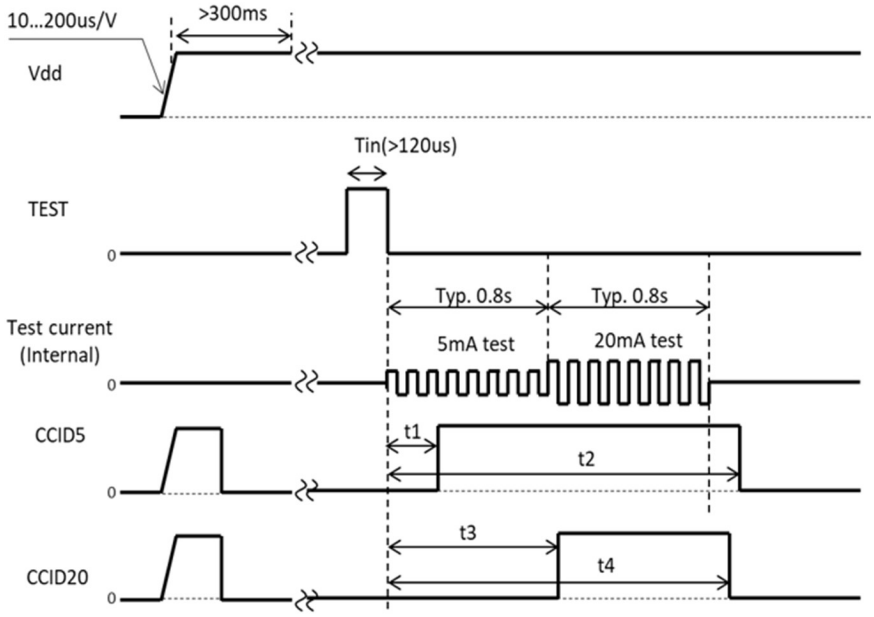
Parameter	Minimum	Maximum
t1	0.12	0.60
t2	0.80	1.30
t3	0.70	1.20
t4	1.40	2.10

Self-Test Operation cont.

FG-R01-4GA



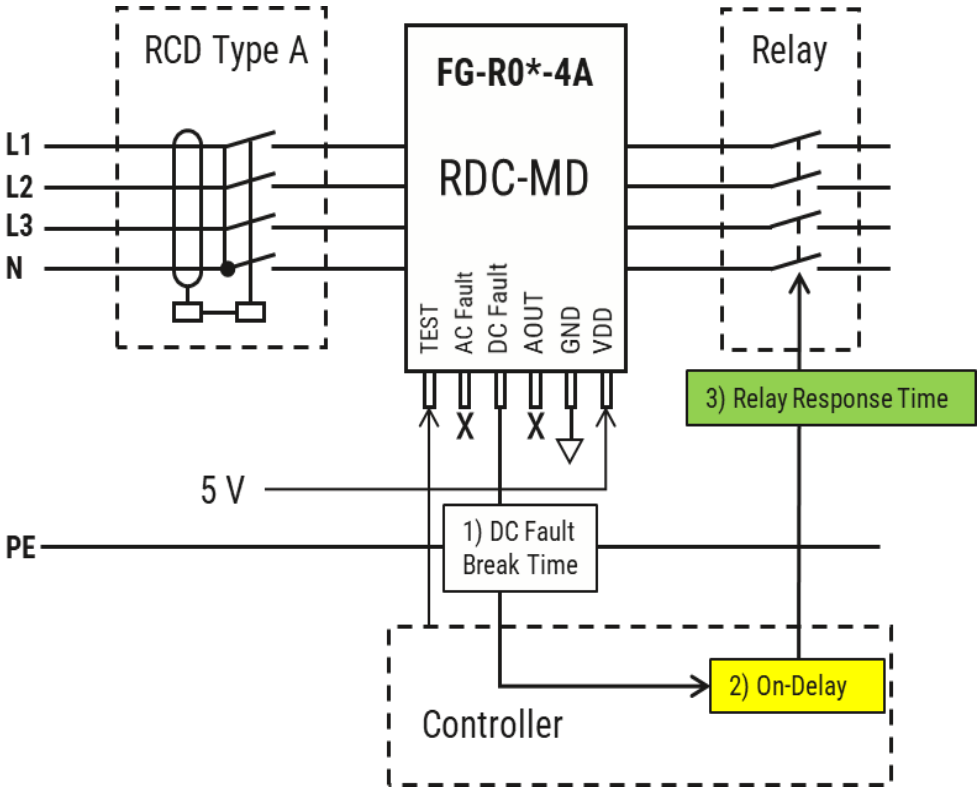
Time Chart



Parameter	Minimum	Maximum
t1	0.03	0.20
t2	1.40	2.10
t3	0.70	1.20
t4	1.40	2.10

Recommended Circuit

Typical Configuration Diagram



Appendix 3 Regarding Applying RDC-MD for 4A Type

FG-R0*-4A is tripped DC fault with high AC residual current of more than 60 mA.
When using the sensor as RDC-MD, break times are faster than required non-operating time.
You need to set a delay time to keep above minimum and below maximum response time at non-operating time.
An example of setting the delay time for the controller is shown above.
The delay is only needed when tripping on DC only. If both alarms are used fro tripping no delay is required.

Recommended Circuit (cont.)

Calculation Example Based on Typical Values

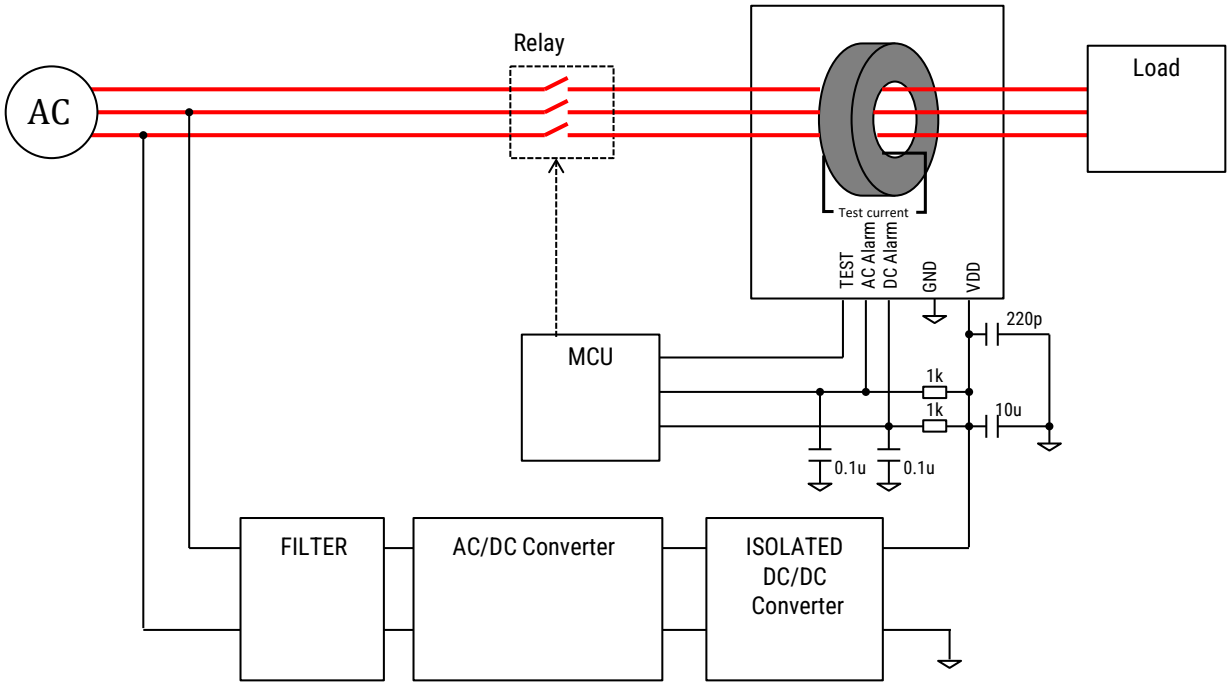
- **On-delay needed: 69 ms**
- **Relay break time (typical): 15 ±4 ms (11 ~ 19 ms)**

Residual Currents	IEC62955 Requirement		FG-R02-4A	2) Add Delay (ms)	3) Add Relay Response Time (ms)
	Break Times (ms)	Response Non Operating Time (ms)	1) DC Fault Break Time (ms)		
DC 6 mA	≤10,000	N/A	≤1,000	≤1,069	<1,088
DC 60 mA	≤300	N/A	≤100	≤169	<188
DC 200 mA	≤100	N/A	≤12	≤81	≤100
≤AC 30 mA	N/A	No DC Tripping	No DC Tripping	No DC Tripping	No DC Tripping
AC 60 mA	N/A	≥300	No DC Tripping	No DC Tripping	No DC Tripping
AC 150 mA	N/A	>80	>6	≥75	≥86
AC 5 A	N/A	>80	>0	≥69	≥80

+69 +19 +69 +11

Recommended Circuit (cont.)

FG-R01-4A,4BA

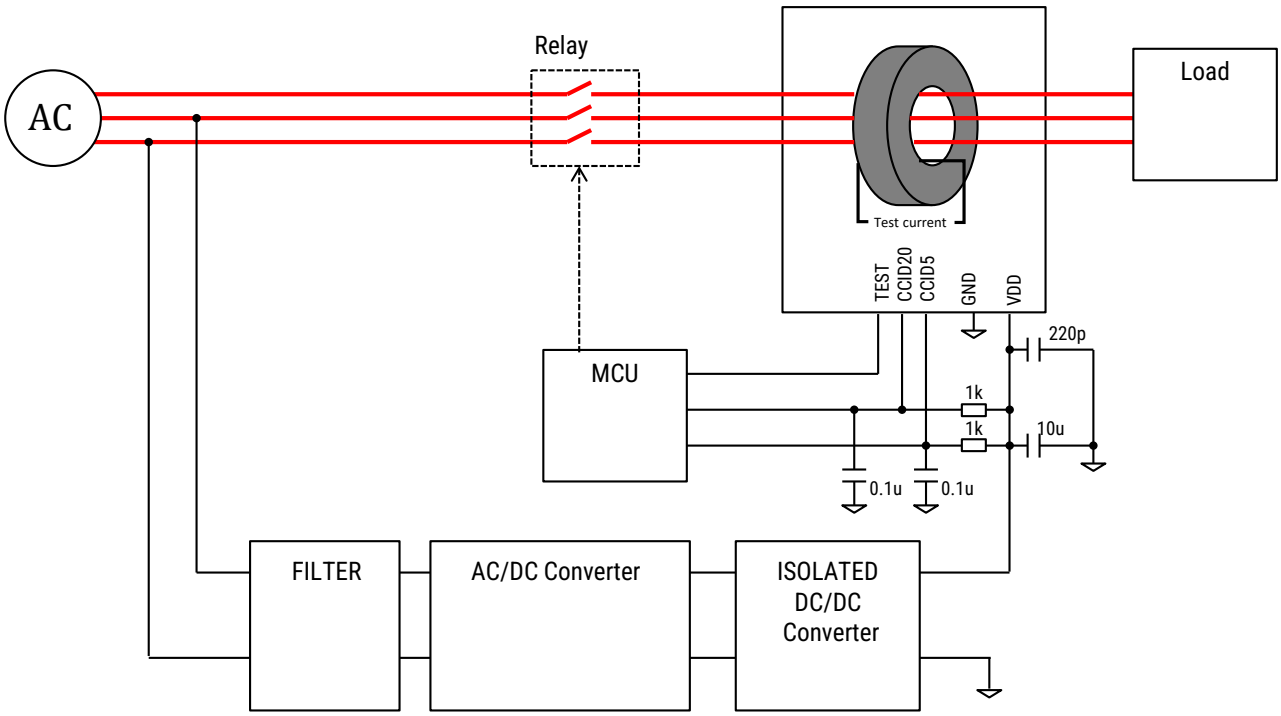


Application Hints

- Adding a capacitor of a few hundred pF or less to the VDD improve high frequency noise immunity.
- Adding capacitors to between the AC / DC Alarm and GND improve noise immunity.

Recommended Circuit (cont.)

FG-R01-4GA



Application Hints

- Adding a capacitor of a few hundred pF or less to the VDD improve high frequency noise immunity.
- Adding capacitors to between the CCID 20/ CCID 5 and GND improve noise immunity.

Handling Precautions

Precautions for Product Storage

Current sensors should be stored in normal working environments. While the sensors are quite robust in other environments, exposure to high temperatures, high humidity, corrosive atmospheres, and long-term storage degrade solderability.

KEMET recommends that maximum storage temperature not exceed 85°C and atmospheres should be free of chlorine and sulfur-bearing compounds. Temperature fluctuations should be minimized to avoid condensation on the parts. Avoid storage near strong magnetic fields, as they can magnetize the product and cause its characteristics to change. Limit ambient magnetic fields to 50e or less.

For optimized solderability, the stock of current sensors should be used within 12 months of receipt.

Before Using Fluxgate-Based Residual Current Sensors

- Do NOT drop or apply any other mechanical stress, as such stresses may change performance characteristics.
- Do NOT exceed 260°C for 10 seconds when soldering. This is the maximum heat resistance grade of these sensors. Use a low-corrosion type flux when soldering.
- Do NOT allow strong static electricity near the sensor, as the circuit uses ICs. Static electricity can cause damage. Take static electricity precautions when handling.
- The case is Insulation Materials Group III. When desiging the primary wire, be careful of clearance and creepage distance from the input/output terminal.

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