

JJ146 Bipolar Leakage Breaker Detection IC

Rev.2.0

DESCRIPTION:

The JJ146 is a low-power controller for AC outlet Appliance Leakage Circuit Interrupters (RCD) and two wire Residual Current Devices (RCD). The JJ146 detects hazardous grounding conditions and open circuits the line before a harmful shock occurs.

Internally, the JJ146 contains a diode rectifier, precision bandgap 12V shunt regulator, precision low VOS offset-sense amplifier, time delay noise filter, window-detection comparators, and a SCR driver. With the addition of a minimum number of external components, the JJ146 detects and protects against a hot-wire-to-ground fault. The minimum number of components and the small package allow for a small-form-factor, low-cost application solution.

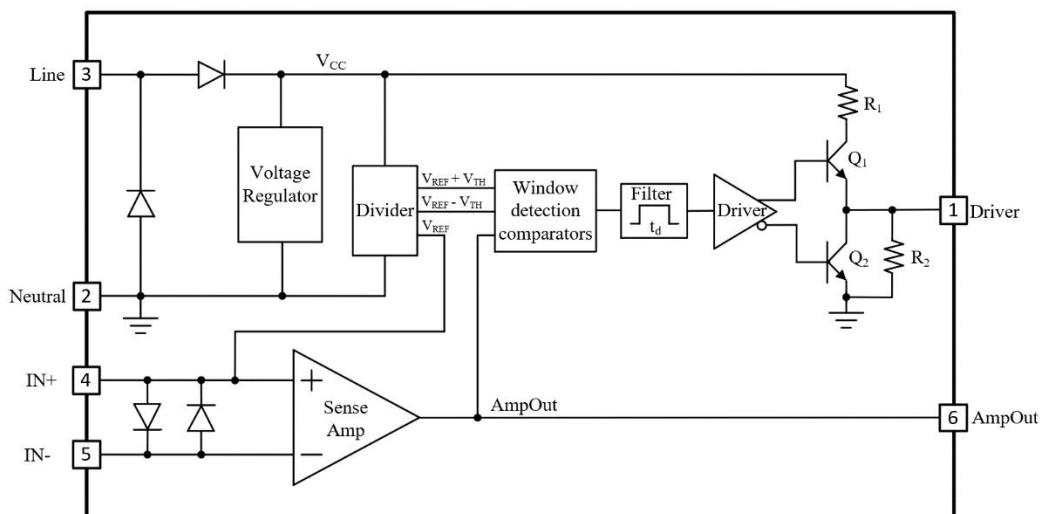
MAIN FEATURES:

- ☆ Built In Half Wave Rectification And Power Supply Voltage Stabilizing Module
- ☆ Low Offset Amplifier
- ☆ Bidirectional Threshold Comparator
- ☆ Anti Interference Delay
- ☆ Under voltage Protection
- ☆ Adjustable Detection Sensitivity
- ☆ SOT23-6 Package
- ☆ Meets UL 943B Requirements
- ☆ Suitable For Various Voltage Systems

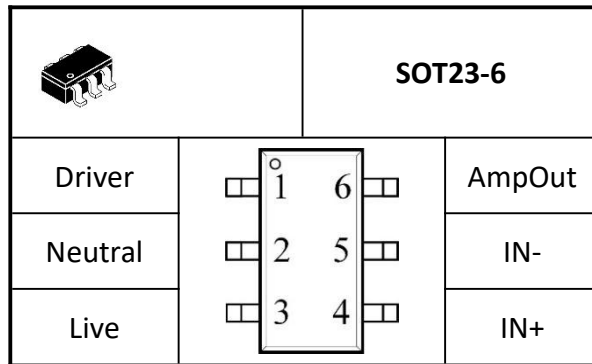
Application:

- ◇ RCD

Block Diagram:



Package and Pin Definition:



No.	Pin.Name	Functions DeDriveription
1	Driver	Drive output
2	Neutral	Zero line input
3	Live	Firewire input
4	IN+	Positive end of amplifier
5	IN-	Inverting end of amplifier
6	AmpOut	Amplifier output

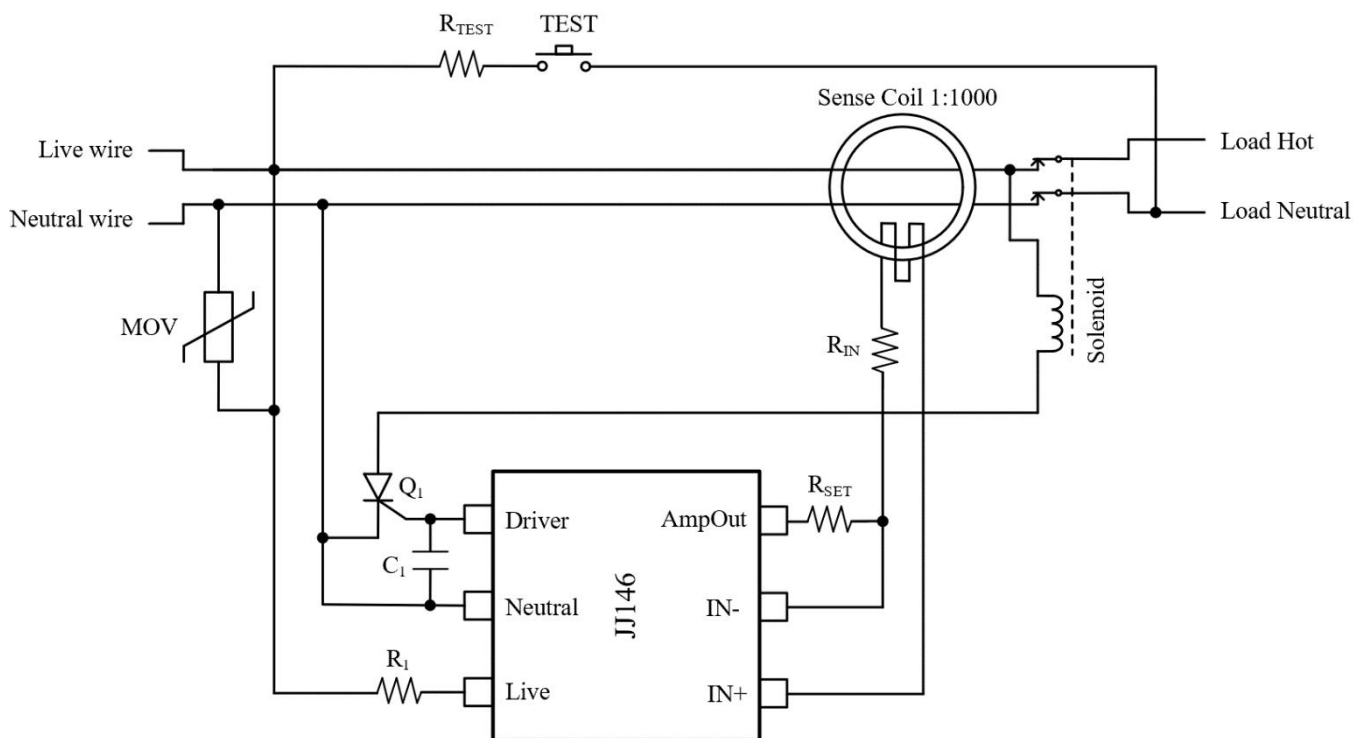
ABSOLUTE MAXIMUM RATINGS

Description		Symbol	Value range	Unit
Supply Voltage	Continuous Voltage, Line to Neutral	V _{CC}	-1.5~16.0	V
	Continuous Voltage to Neutral (All other pins)		-0.8~15.0	V
Supply Current	Continuous Current, Line to Neutral	I _{CC}	15	mA
Storage Temperature Range		T _{stg}	-65~150	°C
Electrostatic Discharge Capability	HBM	ESD	2500	V
	CDM		1000	
	MM		200	

ELECTRICAL CHARACTERISTICS ($T_j=25^{\circ}\text{C}$ unless otherwise specified, $I_{\text{shunt}} = 1\text{mA}$.)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Units
Quiescent Current	I_Q	Live to Neutral = 10V	450	500	550	μA
Reference Voltage	V_{REF}	IN+ to Neutral	5.8	6.0	6.2	V
Power Supply Shunt Regulator Voltage	V_{REG}	Live to Neutral	12.2	12.7	13.2	V
		Live to Neutral, $I_{\text{shunt}}=-2\text{mA}$	-0.9	-0.6	-	V
Amplifier Offset	V_{OS}	$R_{\text{SET}} = 511\text{K}\Omega$, $R_{\text{IN}} = 500\Omega$	-350	0	350	μV
Amplifier Input Offset	I_{OS}	Design Value	-50	0	50	nA
Amplifier DC Gain	Gain	Design Value	-	100	-	dB
Amplifier Gain Bandwidth	f_{GBW}	Design Value	-	1.5	-	MHz
Amplifier Current Sink	I_{SINK}	AmpOut = IN+ + 3V, IN- = IN+ + 100mV	400			μA
Amplifier Current Source	I_{SRL}	AmpOut = IN+ - 3V, IN- = IN+ - 100mV	400			μA
Amplifier Positive Voltage Swing	$V_{\text{SW+}}$	AmpOut to IN+, $I_{\text{FAULT}} = 10\mu\text{A}$	4.0	-	-	V
Amplifier Negative Voltage Swing	$V_{\text{SW-}}$	IN+ to AmpOut, $I_{\text{FAULT}} = -10\mu\text{A}$	4.0	-	-	V
Trip Threshold	V_{TH}	AmpOut to IN+	3.4	3.5	3.6	V
Delay Filter	t_d	Delay from Comparator Trip to Driver L to H	0.75	1.00	1.25	ms
Drive output low level	V_H	Driver to Neutral, AmpOut=IN+	-	1	10	mV
Drive output high level	V_L	Driver to Neutral, AmpOut = IN+ + 4V	2.5	-	-	V
SCR Output Current	I_{OUT}	Driver to Neutral = 1V, AmpOut = IN+ + 4V	350	500		μA
SCR Output Resistance	R_{OUT}	DRIVER to Neutral = 250mV, AmpOut = IN+	-	0.5	1	K Ω

Typical Applications



Typical value:

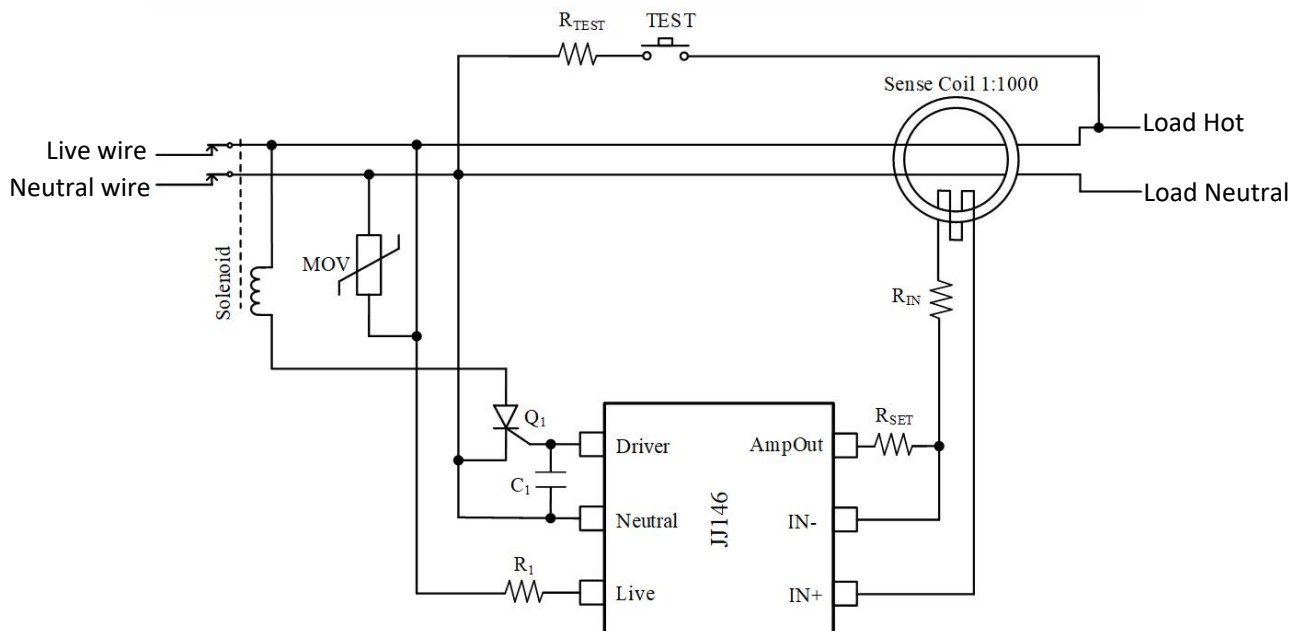
R_1 : 91 k Ω (Wattage Determined by Maximum VAC)

R_{IN} : 470 Ω

R_{TEST} : 15 k Ω

C_1 : 22 nF

R_{SET} : 511 k Ω



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Functional Description

The JJ146 is a two-wire RCD controller for AC ground-fault-circuit interrupters. The internal rectifier circuit is biased by the AC line during the positive half cycle of the AC line voltage. The internal 12V shunt regulator uses a precision temperature-compensated bandgap reference. The combination of precision reference circuitry and precision sense amplifier provides for an accurate ground-fault tolerance. This allows for selection of external components with wider and lower-cost parameter variation. Due to the low quiescent current, a high value external series resistor(R1) can be used which reduces the maximum power wattage required for this resistor. The 12V shunt regulator generates the reference voltage VREF for the sense amplifier's (A1) non-inverting input (AC ground reference) and supplies the bias for the delay timer (t1), comparators (C1 & C2), and the SCR driver. The secondary winding of the sense transformer is directly DC coupled to the inverting input of the sense amplifier at pin 5 (VFB). The RSET resistor converts the sense transformer's secondary current to a voltage at pin 6 (AmpOut). This voltage is compared to the internal window comparator (C1 & C2) and, when the AmpOut voltage exceeds the +/-VTH threshold voltage, the window comparator triggers the internal delay timer. The output of the window comparator must stay HIGH for the duration of the t1 timer. If the window comparator's output momentarily goes LOW, the t1 timer resets. If the window comparator's output is still HIGH at the end of the t1 pulse, the SCR driver enables the current source I1 and disables Q1. The current source I1 then enables the external SCR, which energizes the solenoid, opens the contact switches to the load, and removes the hazardous ground fault. The window comparator allows detection of a positive or negative IFAULT signal independent from the phase of the line voltage. An internal under-voltage lockout circuit disables the SCR driver if the voltage at pin 3 (LINE) is below 7.5V. This prevents the SCR from energizing the solenoid when the SCR's anode voltage is below 50V.

The sense transformer typically has a toroidal core made of laminated steel rings or solid ferrite material. The secondary of the transformer is typically 1000 turns of #40 wire wound through the toroid. The primary is typically one turn made by passing the AC hot and neutral wires through the center of the toroid. When a ground fault exists, a difference exists between the current flowing in hot and neutral wires. The primary difference current divided by the primary-to-secondary turns ratio is the current that flows through the secondary wire of the transformer.

Calculation of RSET Resistor :

The AmpOut signal must exceed the window comparator's VTH threshold voltage for longer than the delay timer and calculated by:

$$V_{TH} = I_{FAULT} \times 1.41 \times R_{SET} \times \frac{\cos(2\pi \times \frac{t}{2P})}{N}$$

$$R_{SET} = \frac{V_{TH} \times N}{1.41 \times I_{FAULT} \times \cos(\pi \times \frac{t}{P})}$$

where: $V_{TH} = 3.5 \text{ V}$

$I_{FAULT} = 5 \text{ mA}$ (UL943B)

$t = 1 \text{ ms}$ (timer delay)

$P =$ Period of the AC Line

$N =$ Ratio of secondary to primary turns (1000:1)

$R_{SET} = 505 \text{ k}\Omega$ (511k Ω standard 1% value)

In practice, the transformer is non-ideal, so RSET may need to be adjusted by up to 30% to obtain the desired fault trip threshold.

Calculation of VOS Trip Threshold Error :

Since the sense coil is directly connected to the feedback of the sense amplifier, the VOS offset introduces an I_{fault} threshold error. This error can be:

$$\%Error = 100 \times \frac{\frac{V_{OS} \times R_{SET}}{R_{IN} \times RL_{DC} \times RL_{AC}}}{V_{TH}}$$

where: $V_{OS} = \pm 300 \mu\text{V}$ (worst case)

$= \pm 150 \mu\text{V}$ (typical)

$R_{SET} = 511 \text{ k}\Omega$

$R_{IN} = 470 \Omega$ (typical)

$RL_{DC} = 75 \Omega$ (sense coil secondary DC resistance)

$RL_{AC} = 1.5 \text{ k}\Omega$ (AC(j ω L) impedance of sense coil), $L = 4 \text{ H}$, $f = 60 \text{ Hz}$

$V_{TH} = 3.5 \text{ V}$

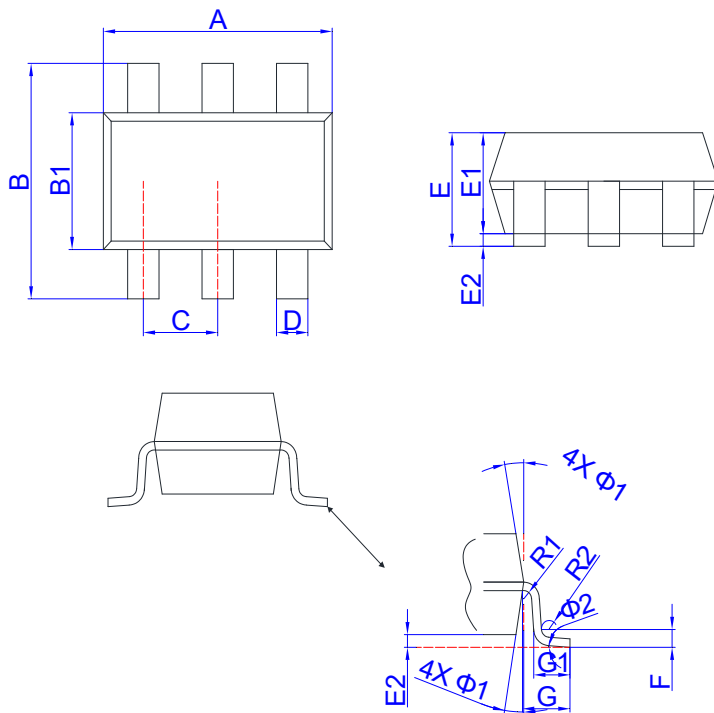
$\%Error = \pm 2.2 \%$ (worst case)

$= \pm 1.1 \%$ (typical)

ORDERING INFORMATION

Order code	Package	Base qty. (pcs)	Delivery mode	MPQ (pcs)	MOQ (pcs)
JJ146-M	SOT-23-6	3K	Tape and Reel	30K	120K

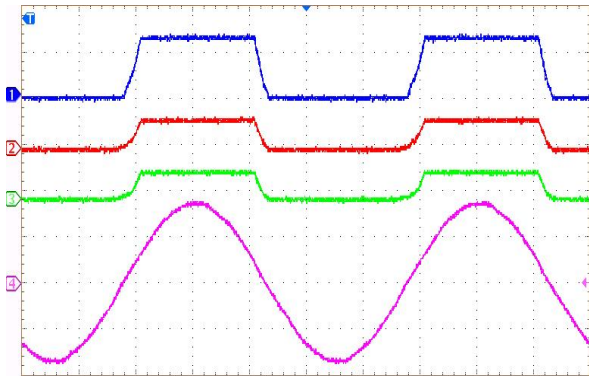
Package dimensions



Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.82	2.92	3.02	0.111	0.115	0.119
B	2.60	2.80	3.00	0.102	0.11	0.118
B1	1.526	1.62	1.726	0.06	0.064	0.068
C	0.90	0.95	1.00	0.035	0.037	0.039
D	0.35	-	0.45	0.014	-	0.018
E	-	-	1.35	-	-	0.053
E1	1.00	1.10	1.20	0.039	0.043	0.047
E2	0	-	0.15	0	-	0.006
F	0.25REF			0.01REF		
G	0.6REF			0.024REF		
G1	0.35	0.45	0.60	0.014	0.018	0.024
R1	0.10	-	0.25	0.004	-	0.01
R2	0.10	-	-	0.004	-	-
Φ1	5°	10°	15°	5°	10°	15°
Φ2	0°	4°	8°	0°	4°	8°

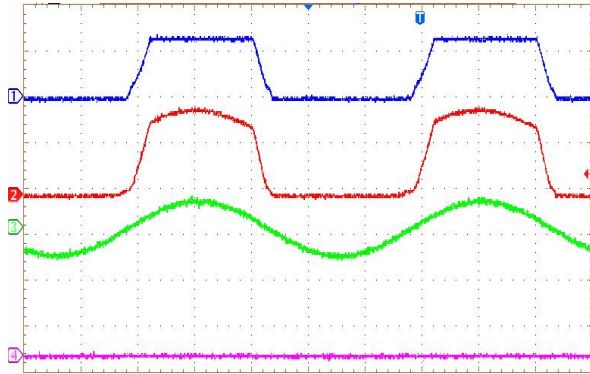
Typical characteristics (Test according to typical application diagram, $T_a=25^\circ\text{C}$)

Typical Waveforms, No Ground Fault



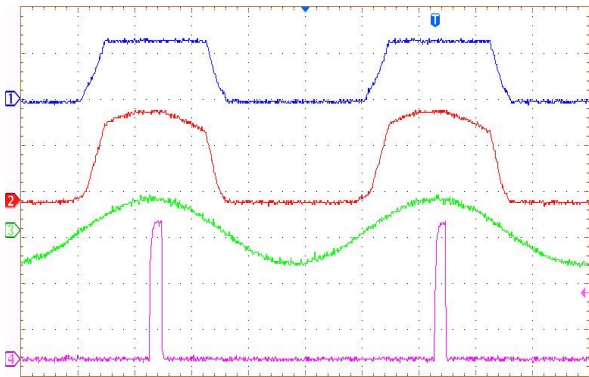
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (10V/DIV)
 CH3: V_{IN+} (10V/DIV)
 CH4: V_{AC} (100V/DIV)
 Time: 4ms/DIV

4mA Ground Fault



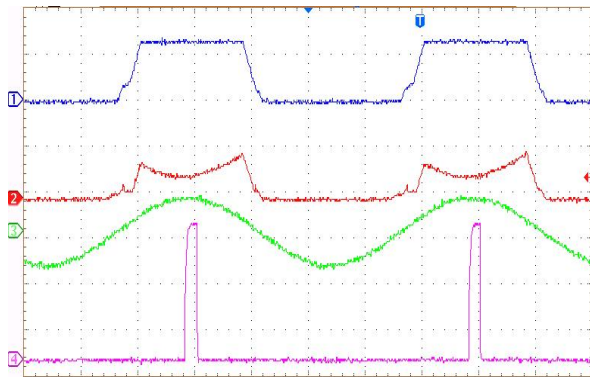
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (10mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 4ms/DIV

5mA Ground Fault



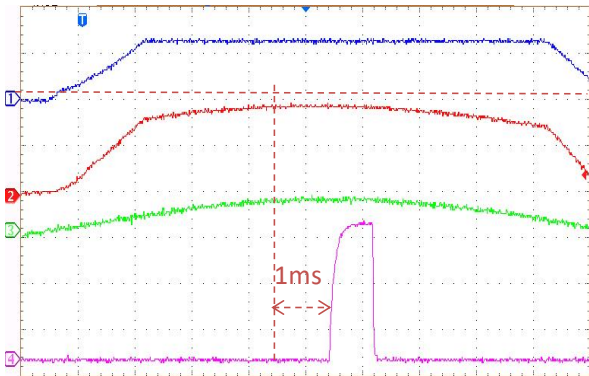
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (10mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 4ms/DIV

5mA Ground Fault (coil reverse)



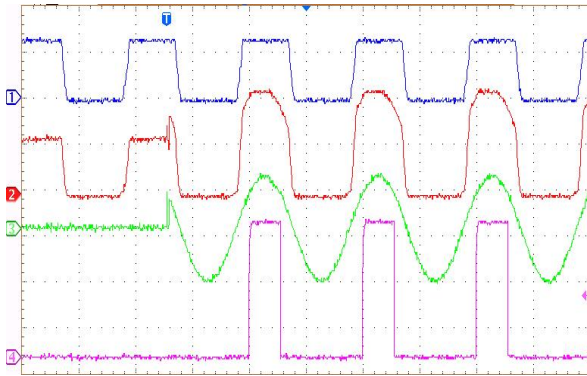
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (10mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 4ms/DIV

Internal Filter Delay



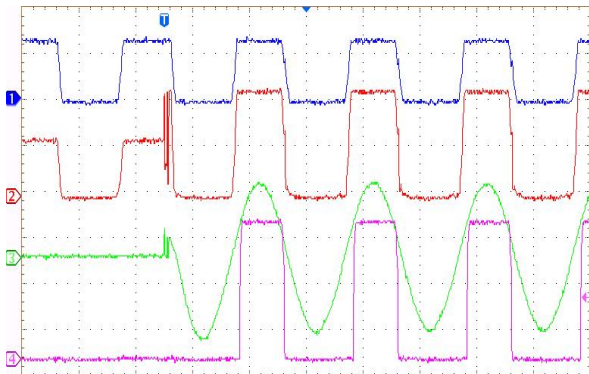
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (10mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 1ms/DIV

15K Ω Ground Fault



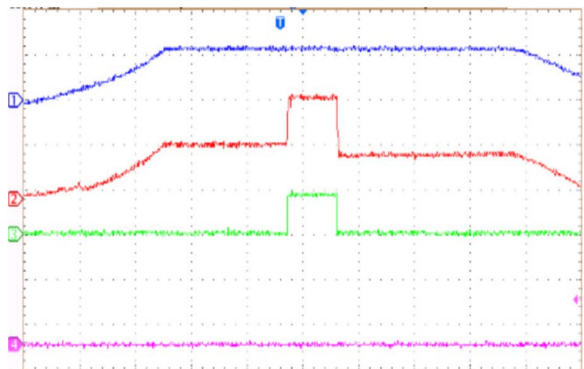
CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (10mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 10ms/DIV

500 Ω Ground Fault



CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (200mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 10ms/DIV

Internal Filter Delay (Fault Time < 1ms)



CH1: V_{LIVE} (10V/DIV)
 CH2: Ampout (5V/DIV)
 CH3: I_{FAULT} (20mA/DIV)
 CH4: Driver (1V/DIV)
 Time: 1ms/DIV
 Fault time is slightly less than 1ms,
 Driver not triggered.

Document Revision History

Date	Revision	Changes
Oct 1, 2020	1.0	Tanzhi
Apr 25, 2022	2.0	Frank Yan