Solid State High Voltage Contactor Controller

Description:

Sensitron's High Voltage Contactor Controller uses solid state technology and when joined with an external contactor or relay (simplified as Contactor), the contactor controller creates a hybrid switch. When connected to a capacitive load bank in the application system, the hybrid switch limits inrush current during turn-on and removes damaging spike voltages on the external Contactor during turn-off. Where reliability is concerned, this hybrid switch can provide extended life and performance.

Applications:

- Main DC Bus Switch
- DC Motor Bus Switch
- Battery Disconnect
- Bus Discharge

Features:

- Turn on or turn off external Contactor at low shunt voltage to minimize its make arc or break arc
- Limit load capacitor bank pre-charge inrush current to typical 20A, across full operating temperature range
- Report fault when no external Contactor is connected
- Report short circuit fault at connected load
- Fault-free activation of external Contactor
- Requires 6V to 36V supply voltage to VBIAS for operation
- Built-in transient voltage suppressor, typically 100V, between power terminals V1 and V2
- Isolation of 1500V: Control Input / Output to Power terminals; Control Input / Output and Power terminals to Baseplate
- 3.20" X 1.56" X 1.20", see outline drawing

Theory of Operation:

When combined with an external Contactor, the SCC020D300 Contactor Controller creates a hybrid switch that provides inrush current limiting and turns on short circuit protection for high voltage DC system applications- with minimal break or make arc on external Contactor.

OFF MODE: Hybrid switch is not activated when VBIAS supply is lower than minimum operating voltage 18V, and there is no load current flowing through either Contactor Controller or external Contactor

TURNING ON: Hybrid switch is activated from OFF mode, when VBIAS supply goes above minimum operating voltage. Contactor Controller starts conducting load current while limiting the current below 50A. Load current will be transferred from Contactor Controller to external Contactor when it's closed by Contactor Controller.

When load current flowing through Contactor Controller is higher than short circuit protection level 60A or there is an electrical system anomaly during the process, Contactor Controller goes into Fault mode and external Contactor won't be turned on.

STAND-BY MODE: external Contactor is in closed state and conducting current. Due to higher impedance of Contactor Controller versus external Contactor, very tiny load current is shunted through Contactor Controller while external Contactor carries most load current. Short circuit protection is not applicable.

TURNING OFF: Contactor Controller activates from the stand-by mode and initiates the shutdown sequence, when VBIAS goes below minimum operating voltage. External Contactor will be turned off and load current will be transferred from external Contactor to Contactor Controller. Contactor Controller will be turned off at the end and goes to OFF mode, no current flows to load through either Contactor Controller or external Contactor.

FAULT MODE: Contactor Controller keeps both external Contactor and itself open and set FAULT pin high when fault condition is detected. No current flows to load through either Contactor Controller or external Contactor.

Contact Controller Block Diagram and Application

Figure 1 shows the block diagram of Contactor Controller and typical application connections when used with an external Contactor:

The two power terminals (V1 and V2) of Contactor Controller are connected to both contacts of external Contactor: one terminal "V1" connects to input supply voltage while the other terminal "V2" connects to the load output, or vice versa.

VBIAS and GND pins connect to 28V control supply, which provides power to internal circuitry of Contactor Controller.

COILREF connects to negative terminal of external Contactor's coil while VBIAS connects to its positive terminal: when COILREF voltage is held at VBIAS by Contactor Controller, coil voltage of external Contactor becomes zero to keep it open; when COILREF voltage is held at GND by Contactor Controller, coil voltage of external Contactor stays at VBIAS voltage level to keep external Contactor closed.

High output voltage level on FAULT pin of Contactor Controller is to indicate short circuit condition at load output or no external Contactor connected. When load short circuit fault is detected by Contactor Controller, it opens external Contactor by driving COILREF same voltage as VBIAS.

Between V1 and V2 terminals of Contactor Controller, two back-to-back connected IGBTs are in series with $R_{limiter}$, which is to limit pre-charging inrush current for load capacitor bank. $R_{limiter}$ is combined with 4 resistors (R_1, R_2, R_3 and R_4) in series, and each resistor of R_1, R_2, and R_3 is connected in parallel with one TRIAC, as shown in Figure 2.
The drive signals to control two back-to-back IGBTs and TRIACs are shown in Figure 3: When SW is driven high to turn on back-to-back IGBTs, R_1, R_2, R_3 are all connected so maximum $R_{limiter}$ is connected between terminal V1 and V2 to limit inrushing current. R_1, R_2, and R_3 are shorted by their parallel connected TRIAC sequentially. The low shunt voltage will reduce the break arc or make arc of external Contactor when it is opened or closed.

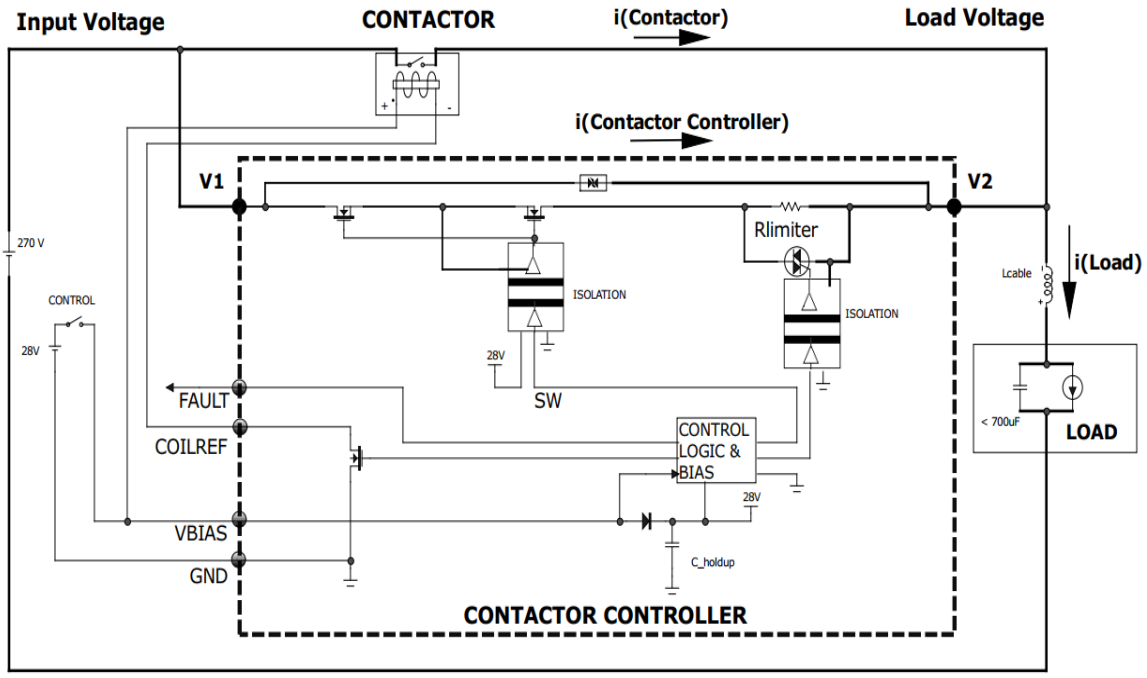


Figure 1: Block Diagram of Contactor Controller and Typical Application Connections

Note: Connections to V1 and V2 can be swapped

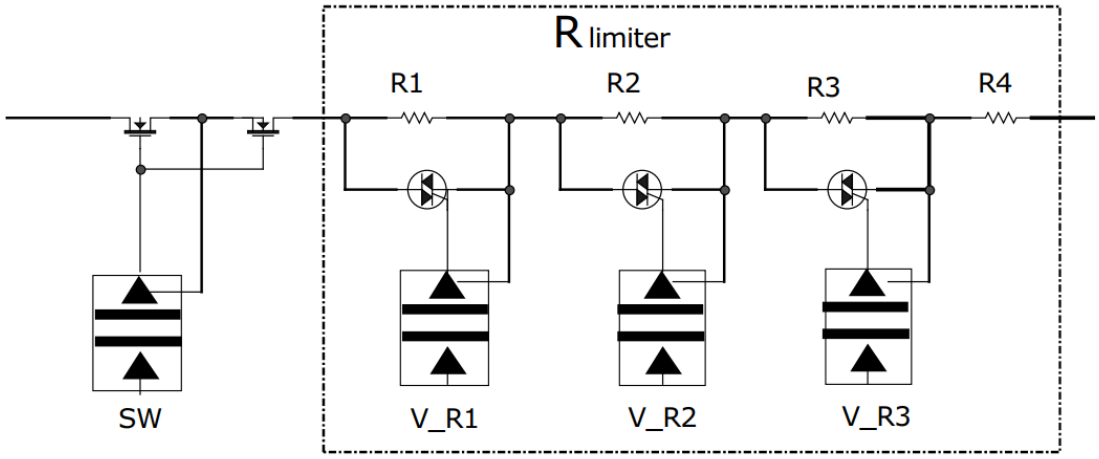


Figure 2: $R_{limiter}$ Structure, R4 is replaced with 0.0 ohms

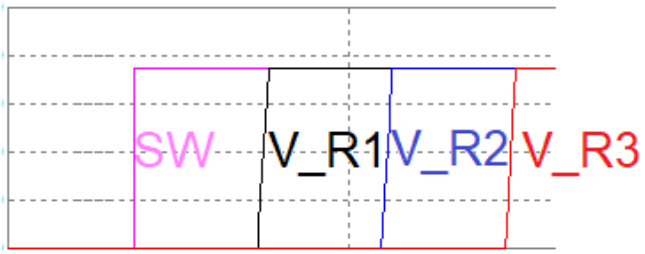


Figure 3: Drive Signals

Figure 4 and Figure 5 show turn on and turn off waveforms for Figure 1 application circuitry: Load is combined with capacitor bank and active circuitry, and active circuitry starts to draw current when its voltage goes above undervoltage protection level.

At turn on, when 28V control voltage stays active (over 18V), for a fixed time duration (t_{on}), Contactor Controller completes internal turning on process by sequentially closing internal switches SW, VR1, VR2, and VR3. The inrush current for charging load capacitor banks is limited by $R_{limiter}$. At td_{on}, the external Contactor coil is energized when Contactor Controller sets COILREF voltage at GND, and external Contactor is turned on to carry load current.

At turn off, when 28V control voltage stays inactive (below 7V), the coil of external Contactor is deenergized immediately. The shunting action of Contactor Controller prevents external Contactor's power terminals from seeing more than a few volts during turn off, which greatly reduces break arc. After a fixed delay td_{off}, a delay to allow external Contactor to become fully open, Contactor Controller disconnects from the load.

Parasitic inductances of the power cabling will generate flyback voltage at time when Contactor Controller is turned off. This potentially destructive voltage is clamped by internal transient voltage suppressor between V1 and V2 of Contactor Controller as the $\frac{1}{2}*L*I^2$ energy is absorbed by Contactor Controller.

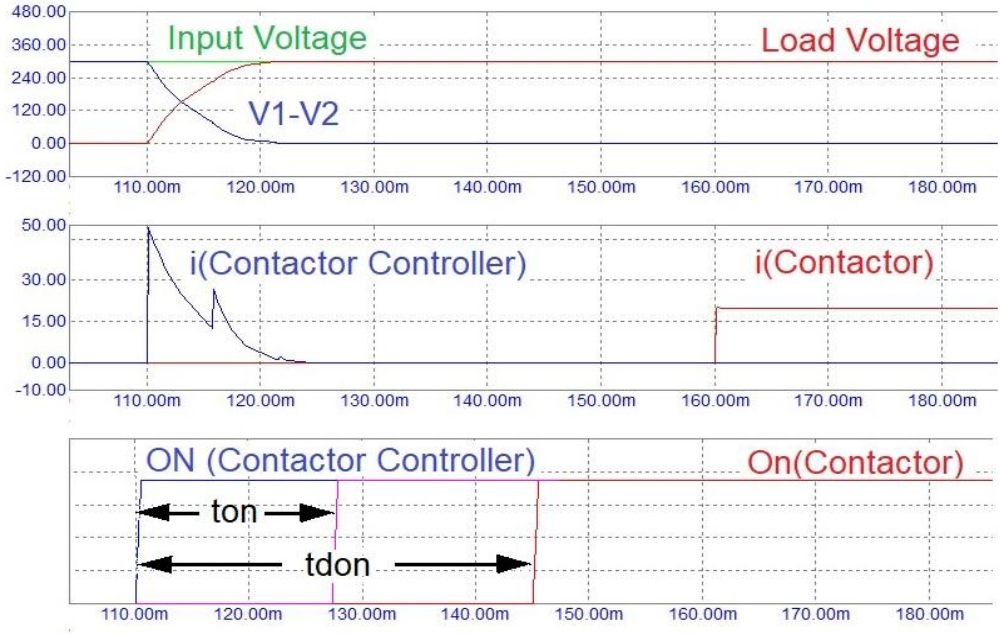


Figure 4: Turn ON Waveforms

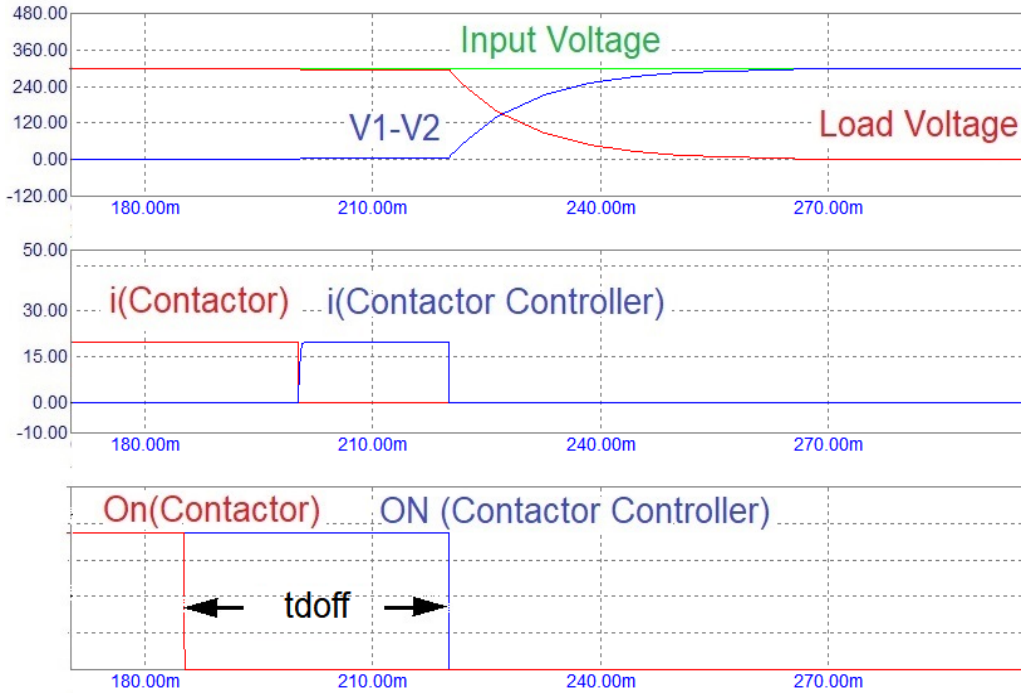


Figure 5: Turn OFF Waveforms

FAULT Output

Contactor Controller is designed to be used with external Contactor, and load current will switch to external Contactor after it is turned on by Contactor Controller. If there is no external Contactor connected, Contactor Controller will handle full load current and thermal runaway can happen. To avoid this issue, Contactor Controller detects if external Contactor is connected. If not, Contactor Controller will turn off and goes into FAULT mode after pre-defined delay time. Figure 6 shows the no external Contactor fault diagram.

Contactor Controller detects if there is short circuit at connected load during the turn-on process. When short circuit condition is detected, FAULT Pin of Contactor Controller is set high and external Contactor won't be turned on. Figure 7 shows load short circuit fault diagram.

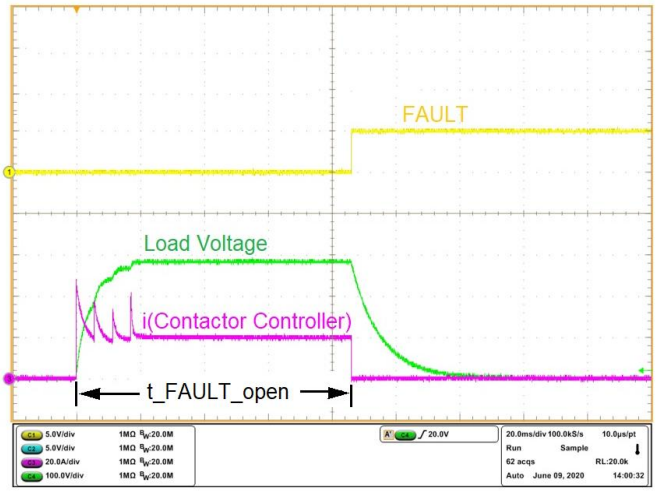


Figure 6: No External Contactor FAULT

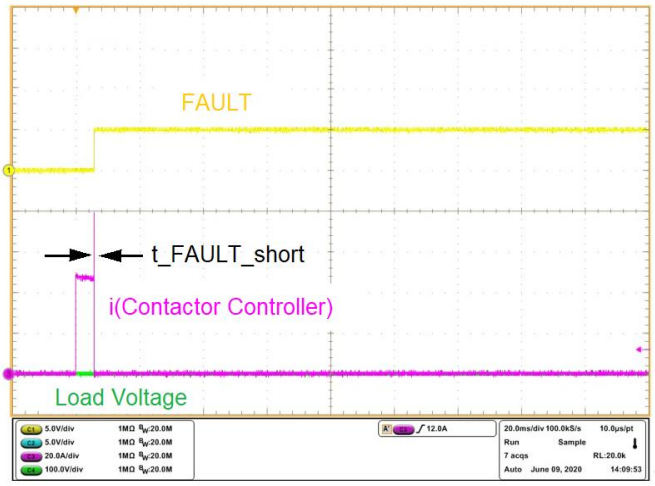
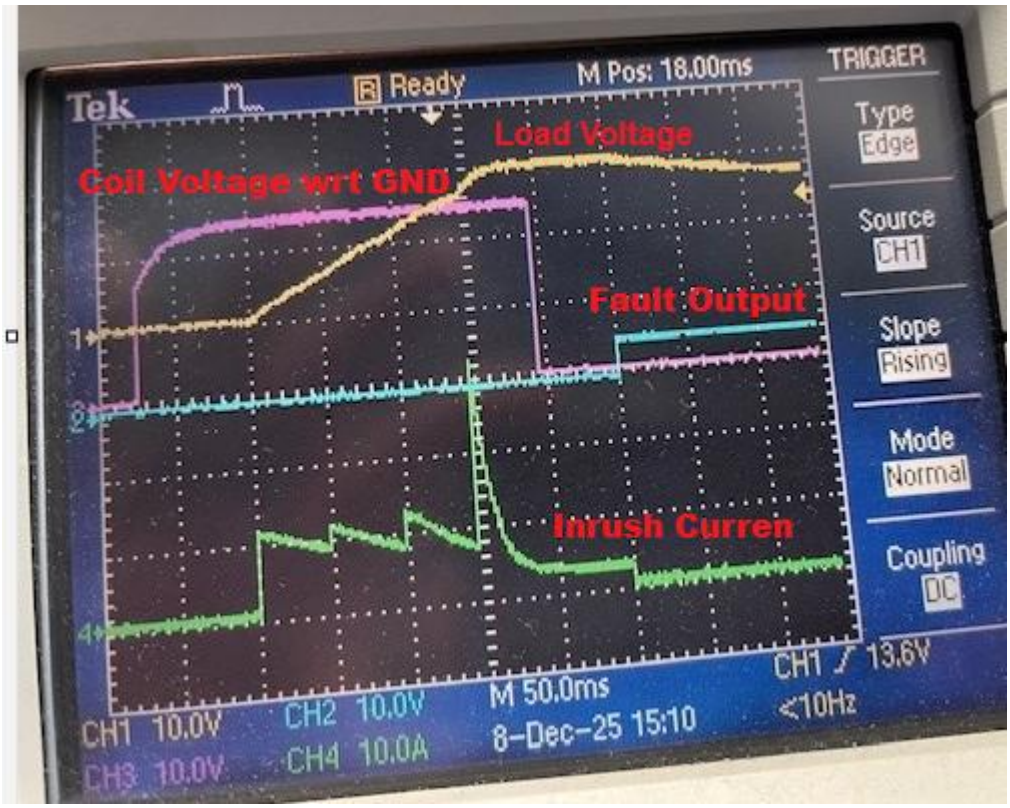
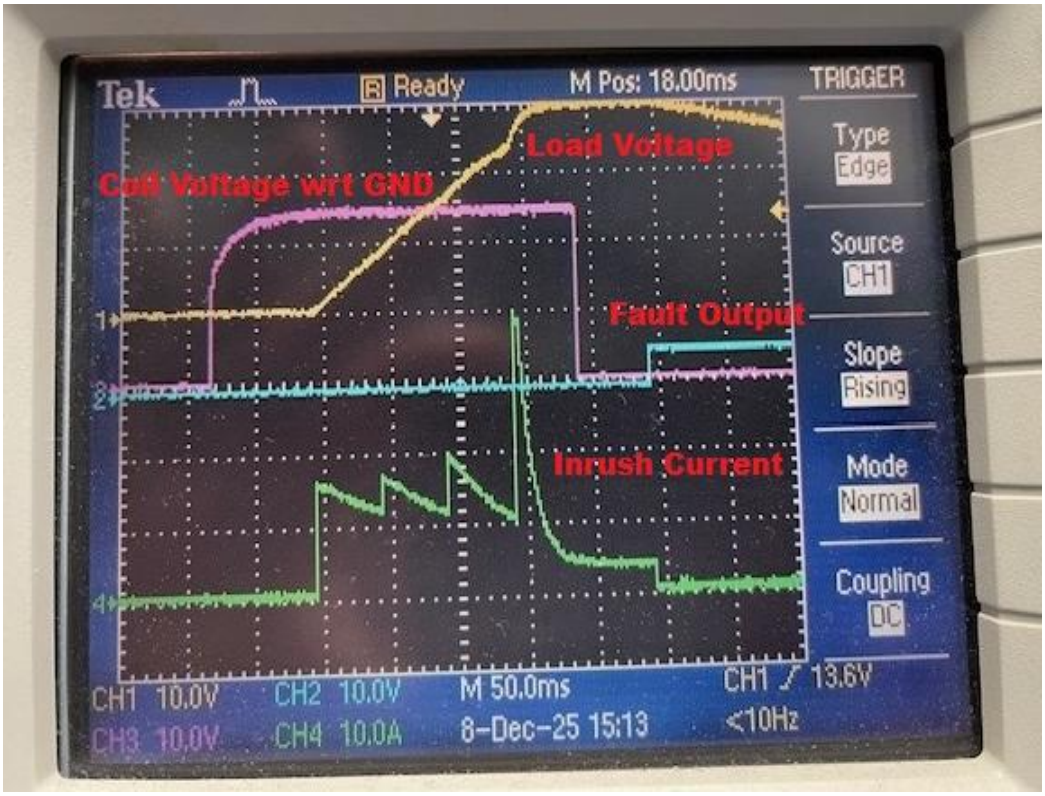


Figure 7: Load Short Circuit FAULT



SCC020D100 Test Conditions:

- **Input Voltage 20V**
- **82mF Capacitive Load**
- **10 Ohm Load Across the Capacitor**
- **Soft Start Charging for 200msec**
- **The Contactor Coil Voltage is activated after 200 msec.**
- **No Contactor is connected in this test to divert the load current from SCC020D100**
- **SCC020D100 shuts down and reports a fault when it detects a current of above 1.5A 50msec after sending the contactor coil voltage**



SCC020D100 Test Conditions:

- **Input Voltage 34V**
- **82mF Capacitive Load**
- **10 Ohm Load Across the Capacitor**
- **Soft Start Charging for 200msec**
- **The Contactor Coil Voltage is activated after 200 msec.**
- **No Contactor is connected in this test to divert the load current from SCC020D100**
- **SCC020D100 shuts down and reports a fault when it detects a current of above 1.5A 50msec after sending the contactor coil voltage**

ELECTRICAL CHARACTERISTICS*:

Control Input / Output ("VBIAS – GND" / "VBIAS – COILREF") Specifications:

Parameter	Description	MIN	TYP	MAX	Unit
VBIAS – GND	Turning on voltage of control input	18	28	36	VDC
VBIAS - GND	Turning off voltage of control input	1.5		7.0	VDC
VBIAS - GND	Absolute maximum voltage	-40		40	VDC
VBIAS – COILREF	Turning on voltage of control output	18	28	36	VDC
VBIAS – COILREF	Turning off voltage of control output			1.5	VDC

Contactor Controller Input / Output (V1 / V2) Specifications for SCC020D300:

Parameter	Description	MIN		TYP	MAX	Unit
V_{Load}	Max voltage on output	-		270	330	V_{DC}
Vin	Max voltage on input	-		270	330	V_{DC}
Peak of $I_{contactor\ ontroller}$	Max inrush current for capacitive load limited by Contactor Controller with 50mF load			50		A
Leak Current	Leakage current of Contactor Controller, when commanded off @ 25°C When commanded off @ 100°C				0.5 25	uA uA
Rshunt	Shunt resistance of Contactor Controller SCC020D300			6.3		Ohm
Max Load Capacitance	SCC020D300			0.70		mF

Contactor Controller Input / Output (V1 / V2) Specifications for SCC020D100:

Parameter	Description	MIN		TYP	MAX	Unit
V_{Load}	Max voltage on output	-		18	36	V_{DC}
Vin	Max voltage on input	-		18	36	V_{DC}
Peak of $I_{contactor\ ontroller}$	Max inrush current for capacitive load limited by Contactor Controller with 50mF load			20		A
Leak Current	Leakage current of Contactor Controller, when commanded off @ 25°C When commanded off @ 100°C				0.5 25	uA uA
Rshunt	Shunt resistance of Contactor Controller SCC020D100			2.04		Ohm
Max Load Capacitance	SCC020D100			80		mF

**Preliminary values—subject to final verification*

Turning on and Turning off Characteristics for SCC020D300:

Parameter	Description	MIN	TYP	MAX	Unit
t_{on}	The duration from Contactor Controller being turned on to R_Limiter		20		ms
t_{don}	The duration from Contactor Controller being turning on to COILREF being pulled low		30		ms
t_{doff}	The duration from Contactor being turned off to Contactor Controller being turned off		10		ms

Turning on and Turning off Characteristics for SCC020D100:

Parameter	Description	MIN	TYP	MAX	Unit
t_{on}	The duration from Contactor Controller being turned on to R_Limiter		50		ms
t_{don}	The duration from Contactor Controller being turning on to COILREF being pulled low		200		ms
t_{doff}	The duration from Contactor being turned off to Contactor Controller being turned off		10		ms

Fault

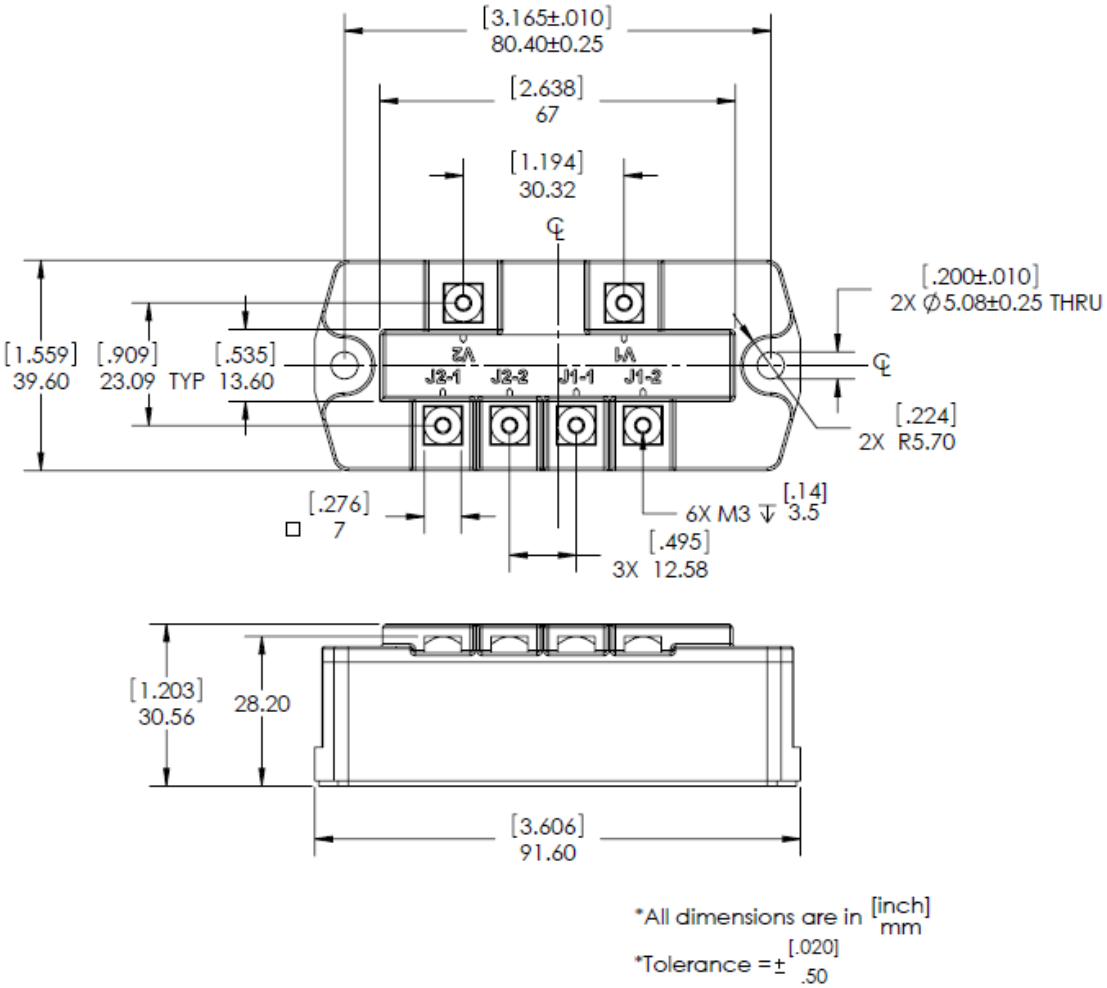
Parameter	Description	MIN	TYP	MAX	Unit
I_OH_FAULT	High-level output current of FAULT			-20	mA
I_OL_FAULT	Low-level output current of FAULT			20	mA
V_OH_FAULT	High-level output voltage of FAULT		5		V
V_OL_FAULT	Low-level output voltage of FAULT		0		V
I_FAULT_short	Contactor Controller short circuit current level		60		A
t_FAULT_short	Time for FAULT goes high when load short is detected			0.5	ms
t_FAULT_open	Time for FAULT goes high when external Contactor is not connected. 50msec after coil voltage is activated			50	ms

Environmental

Parameter	Description	MIN	TYP	MAX	Unit
Isolation	Control Input / Output to power terminals, <1mA	1500	-	-	VDC
Isolation	Control Input / Output and power terminals to Case, <1mA	1500	-	-	VDC
T_{STG}	Storage Temperature	-55	-	150	ºC
T_{CASE}	Operating Temperature (Baseplate)	-55	-	100	ºC
T_J	Operating Temperature (Junction)	-55	-	150	ºC
	Weight	-	150	-	g

Notes:
1. Parameters are characterized on initial design release and upon design changes which would affect these characteristics.

Mechanical Outline:



Pin Assigments:

V1 – Connects to power terminal of external Contactor
V2 – Connects to the other power terminal of external Contactor

VBIAS – Apply control voltage positive to this pin; also connects this pin to the positive terminal of external Contractor coil
GND – Apply control voltage negative to this pin
COILREF – Connects to the negative terminal of external Contactor coil
FAULT – Output from Contactor Controller, indicating short circuit or no external Contactor connected

Note:

- V1 and V2 have no polarity: Connections to V1 and V2 can be swapped.

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