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Brushless DC Motor Controller
Specification
Assemblies 025F0195

600A0866 Rev. F
Feb 14th, 2019

Revision History

Rev	EC#	Date	Description	Initials
A	EC39404	5/26/11	Initial Release	DS
B	EC46424	6/20/12	Updated motor press-fit connectors to M5	DS
C	EC58093	04/04/14	Added cap discharge chart and fixed speed resistor chart	DS
D	EC74518	09/27/16	Added relay fault code	DS
E	EC86995	10/9/18	Added more detail of how to follow the 1V/mSec specification in Appendix B.	CR
F	EC89036	2/14/19	Adjusted the wording in the Fault table	CR

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General Product Description

The 025F0195 Motor Controller has been designed to provide efficient control and fault monitoring of a DC powered brushless hermetic compressor. The controller will provide a constant speed as specified by the speed command inputs unless one of the following limitations is exceeded. Power limitation, this is where the average power the drive is producing exceeds 3800 watts. This is calculated by Power out = motor supply * average motor current. If the load requires more than 3800 watts then the speed will be reduced accordingly. Voltage limitation, this is where the motor supply voltage is not high enough to achieve the commanded speed and or power.

An isolated user interface including an RS-232 serial port is supplied. Run/Stop and speed are controlled by a 0 to 5V analog input, or 0 – 90% PWM input. When the speed input is 1V or less or the duty cycle is less than 15%, the motor is stopped. When the analog input is 1V or the PWM input is 20% the motor will run at 1800 RPM. When the analog input is at 5V, or the PWM input is 80% the motor will run at 6500. Tachometer output is an open collector output signal with 5K pull up resistor. The output frequency is 0 to 2.6 KHz (where 2.6kHz = 6500RPM). When the controller is commanded to run from a stopped condition it will run the motor at 3000 RPM for 30 seconds after which point it will run the motor at the commanded input speed.

The following fault conditions are monitored continuously: under/over voltage, over-current, drive over-temperature, pump over-temperature, low speed and locked rotor. Upon detection of a fault, the controller will shut down the motor. Depending on the cause of the fault the controller may pause to allow time for the fault to clear and then attempt to restart the motor. The fault handling behavior is described further in the fault reporting section. The controller will indicate the fault-state by a TTL output.

Two M5 press-fit connectors are provided for connecting the input power to the controller. Three M5 press-fit connectors will provide connection to the motor outputs for the compressor. A two position locking connector is supplied to connect to the shell temperature switch from the compressor. The isolated control and indicator signals connect to an eight pin locking Molex header. Each connector function is labeled on the printed circuit board. The RS-232 serial port is provided through a nine-pin male dsub connector. The connector pin outs are defined in appendix A.

The motor drive transistor assembly is cooled by a large aluminum finned heat sink. A temperature sensor embedded in the power assembly measures the module temperature. The heat sink provides the mounting points for the assembly with threaded holes at each end. An optional machined heat sink with gasket sealing for thru panel mounting will be available. The heat sink is electrically isolated from the circuitry.

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Calculate fixed speed resistor with the formula below.

$$\text{Resistor} = -\frac{30000 * RPM - 204400000}{3 * RPM - 1640}$$

RPM	Ohms	RPM	Ohms
1800	40000	4200	7153
1900	36305	4300	6696
2000	33119	4400	6263
2100	30343	4500	5852
2200	27903	4600	5461
2300	25741	4700	5088
2400	23813	4800	4734
2500	22082	4900	4395
2600	20519	5000	4072
2700	19102	5100	3763
2800	17811	5200	3467
2900	16629	5300	3184
3000	15543	5400	2912
3100	14543	5500	2651
3200	13618	5600	2401
3300	12760	5700	2160
3400	11963	5800	1929
3500	11219	5900	1706
3600	10524	6000	1491
3700	9873	6100	1285
3800	9262	6200	1085
3900	8688	6300	892
4000	8147	6400	706
4100	7636	6500	526

Resistor to speed chart when using fixed resistor between J4 pins 6 and 7.

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Absolute Maximum Ratings			
Parameter	**Min.**	**Max.**	**Units**
V_M input voltage (steady state)	0	800	V
V_M input voltage (transient, slew rate)		1	V/mS
Analog Speed input (referenced to –Vuser)	-0.3	+5Vuser + 0.3	V
Digital Speed input (referenced to –Vuser)	-0.3	+5Vuser + 0.3	V
Fault output (referenced to –Vuser)	-0.3	+5Vuser + 0.3	V
Fault output current sourced		10	mA
Fault output current sunk		10	mA
Tachometer output current sunk	1		mA
Tachometer output (referenced to –Vuser)	-0.3	+5Vuser + 0.3	V
Storage Temperature	-40°	85°	°C
	-40°	185°	°F

Operating Conditions			
Parameter	**Min.**	**Max.**	**Units**
025F0195			
V_M Input power (D.C.) operating range	495	725	V
V_M low voltage shutdown	460	480	V
V_M low voltage resume	475	495	
V_M high voltage shutdown	740	760	V
V_M high voltage resume	725	745	V
V_M input current (continuous)		5	A
Standby power		5	W
Efficiency (at 1500 watt output, 3000 rpm)	92		%
Ambient	0	65	°C
	32	149	°F
Relative Humidity Range	IEC68-2-30, Damp heat-cyclic 20 – 90% non-condensing @ 0°C (32°F) to 50°C (122°F)		

Note: 65 °C is the ambient temperature that the electronics are rated for. The maximum temperature the heat sink can reach before the microprocessor shuts the drive off is 100 °C (212 °F)

The system designer must provide sufficient airflow to keep the heat sink temperature below its shutdown threshold at the maximum ambient temperature and maximum loading conditions. The controller may fault on over heat sink temperature before reaching the maximum rated current if air flow is insufficient.

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Electrical Characteristics				
Parameter	**Conditions**	**Min.**	**Max.**	**Units**
Isolated +5V User Supply	Iout <= 50 mA	4.95V	5.05V	V
Fault Output Low Voltage (normal operation)	I_{OL} = 8mA		0.6	V
Fault Output High Voltage (Fault)	I_{OH} = -3mA	4		V
Tachometer Output Low Voltage	I_{OL} = 1mA		0.3	V
Analog Speed Input impedance			10K	Ohms
Analog input tolerance	All	+/- 0.1		V
Analog input vs motor speed **See Note 1.**	input <= 0.5V input = 1.0V input = 5.0V	0 1700 6400	 1900 6600	RPM
Digital Speed tolerance	All	+/- 1		%
Digital Speed Input low voltage	+5Vuser = 5.0V		0.8	V
Digital Speed Input high voltage	+5Vuser = 5.0V	4.0		V
Digital Speed Input current			5	uA
Digital Speed Input Frequency	ALL	50	500	Hz
Digital PWM input vs motor speed **See Note 2.**	PWM input <=15% PWM input = 20% PWM input = 80%	0 1700 6400	 1900 6600	RPM
V_M - Ripple Current RMS	Input 5A, 600VDC		1	A
V_M - Average Input Current			5	A
V_M - charging current limiting see **See Note 3.**	On initial application of power		1	A
V_M - Fuse			7.5	A
Module Over temperature	All conditions	90 194	110 230	°C °F

Note 1: The 0 - 5VDC analog signal will provide the speed command. Once the input has gone above the start threshold (1.0V) the input will have to go below 0.5V to turn off (0.5V hysteresis).
Note 2: The 20 – 80% PWM signal will provide the speed command. Once the input has gone above the start threshold (20% duty cycle) the input will have to go below 15% duty cycle to turn off (5% hysteresis).
Note 3: To stay within the current ratings of the in-rush current limiting circuit, the power supply voltage transients must be less than 1 V/mS after the unit is operating and the inrush resistor has been bypassed by the relay. See Appendix B for more information.

The serial interface is configured for 19.2 K baud, 8 data bits, 1 stop bit, no parity, and no flow control. The controller will report the following operating parameters once per second over the serial interface:

> Temperature - module temperature in °C
> Power Supply – Volts
> Current – average current delivered to motor
> Motor Speed – actual speed in RPM
> Fault – in the event of a fault a brief description of the fault is reported (see below)

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Fault Reporting	
STALLED	If the controller detects the compressor shut down while running, delay for 20 seconds and attempt to restart the motor. If the motor does not restart after 10 attempts, the controller will indicate a fault condition by activating the fault indicator output. The controller will continually attempt to restart the motor. If the controller is successful in restarting the motor, the fault indicator will be deactivated after 30 seconds.
STARTUP FAILED	The controller will detect if the motor has failed to start (locked rotor, overload, etc). After a 20 second pause the controller will attempt to restart the motor. If the motor does not start after 10 attempts, the controller will indicate a fault condition by activating the fault indicator output. The controller will continually attempt to start the motor. If the controller is successful in starting the motor, the fault indicator will be deactivated after 30 seconds.
MOTOR OVERHEAT	If the compressor shell temperature switch opens, the controller will shut down the motor and delay for 2 minutes. The controller will indicate the fault condition by activating the fault indicator. After the delay period the controller will recheck the compressor shell temperature switch state. If the compressor shell temperature switch is closed the controller will restart the motor and deactivate the fault indicator.
UNDER / OVER VOLTAGE	If the motor voltage is outside of the operating limits, the controller will shut down the motor and will delay for 10 seconds. After the delay period, the controller will recheck the voltage conditions. If the input voltage is within the operating limits, the motor will attempt to restart.
OVER CURRENT	Hard current limit – if the controller detects an over-current condition it will shut down the motor and activate the fault indicator. The power must be cycled to clear this fault.
MODULE OVERHEAT	If the module temperature rises above 100 °C (212 °F) the controller will shut down the motor and delay for 2 minutes. After the delay period the controller will recheck the module temperature. If the temperature has fallen below 100 °C (212 °F) the controller will restart the motor. The controller will indicate a fault condition by activating the fault indicator. The controller will continue to monitor the module temperature. The controller will restart the motor and deactivate the fault indicator when the module temperature falls below 100 °C (212 °F).
LOW SPEED	The compressor must maintain a minimum speed of 1500 RPM for proper lubrication. If the controller detects a low speed condition, it will shut down the motor, delay for 20 seconds and attempt to restart the motor. If the motor does not restart after 10 attempts, the controller will indicate a fault condition by activating the fault output. The controller will continually attempt to restart the motor. If the controller is successful in restarting the motor and maintaining a speed above 1500 RPM for 30 seconds, the fault indicator will be deactivated
CALIBRATION_TIMEOUT, EEPROM_WRITE_FAILURE	A self-calibration is performed the first time power is applied to the drive. The calibration constants are determined and written to EEPROM. This one-time operation occurs during functional test at the manufacturer. These error messages should not occur in the field.
RELAY FAULT	If the controller is commanded tor run and it measures too high of a voltage across the charge resistor it will open the charge relay and set the relay fault. The controller will delay 240 seconds, after the delay the controller will attempt to restart.

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Appendix A: Connectors

8-pin User Interface Connector Signal Description:

(Molex part number: 70543-0042 eight pin locking connector, mating connector: Molex part number 50-57-9408.)

Pin-1:   NC
Pin-2: -V user (isolated user supply return)
Pin-3: -V user (isolated user supply return)
Pin-4: Digital speed command (input)
Pin-5: Tachometer (output)
Pin-6: +5V user (isolated user supply)
Pin-7: Analog speed command (input)
Pin-8: Fault (output)

Motor Power Connectors:

M5 Press-fit +Vm
M5 Press-fit –Vm

2-pin Compressor Temperature Connector Description:

(Molex part number 70543-0001 two pin locking connector, recommended mating connector Molex part number 50-57-9402)

Pin-1: +Stemp
Pin-2: -Stemp
    Note: This is referenced to the -Udc input, and is not an isolated input.

Motor Connectors:

M5 Press-fit Motor Phase A (output)
M5 Press-fit Motor Phase B (output)
M5 Press-fit Motor Phase C (output)

9-pin Male RS-232 Serial connector:

(Amp part number 3-338309-2)
Pin-2: Rx
Pin-3: Tx
Pin-5: Ground

Appendix B: Input voltage limitations

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The controller is protected by an inrush resistor (RT1) for the first application of voltage. However, once voltage is applied, and the software determines the applied voltage to be stable (both Vsupply and Vbus are measured), then RL1 is closed. After RL1 is closed, the input voltage at J7 and J8 must not transition at rates >1V/mSec. In order to open the relay RL1, voltage must be removed from J7 and J8 for more than 1 minute.
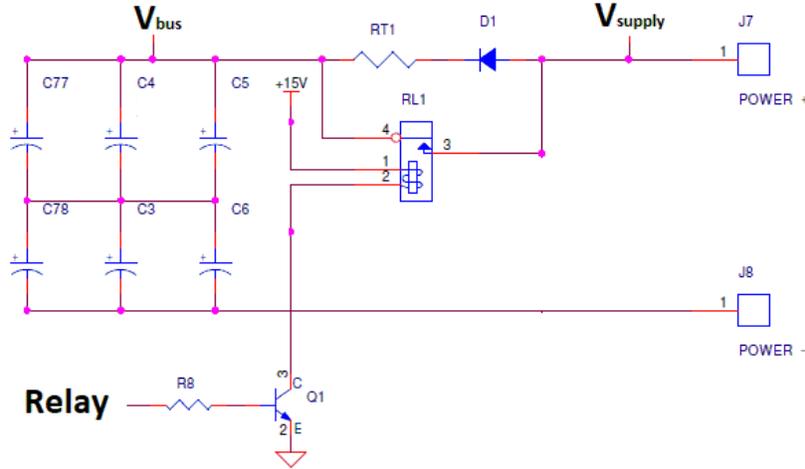
The figure below shows allowable transitions, and not allowable transitions.

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025F0195 Capacitor discharge
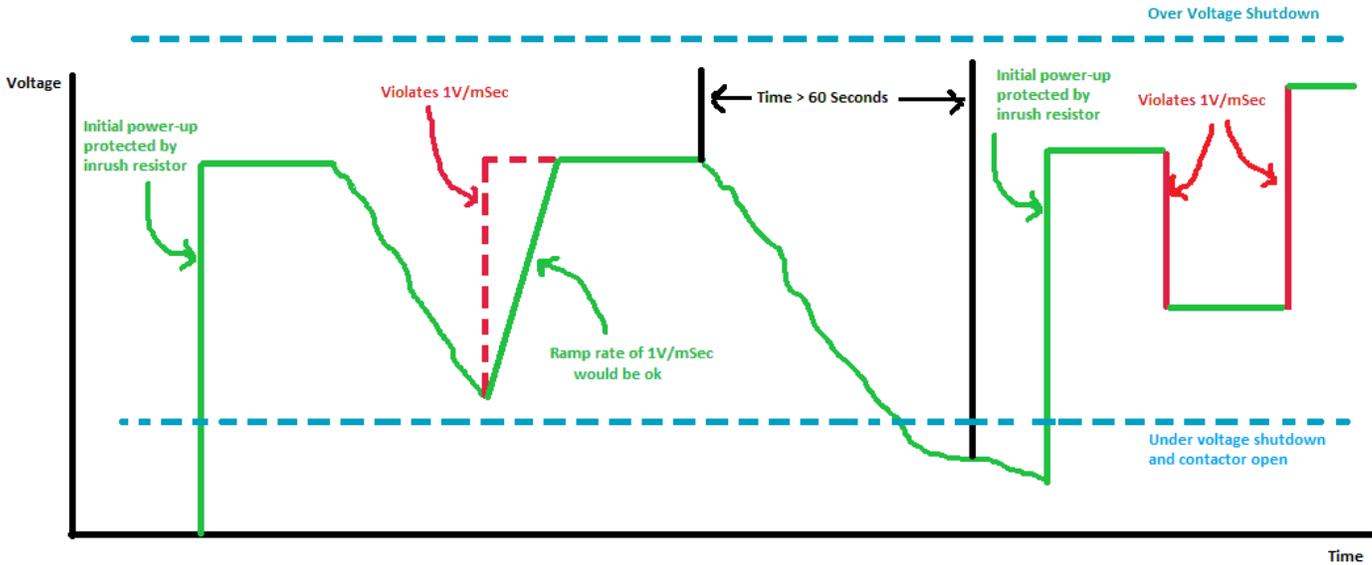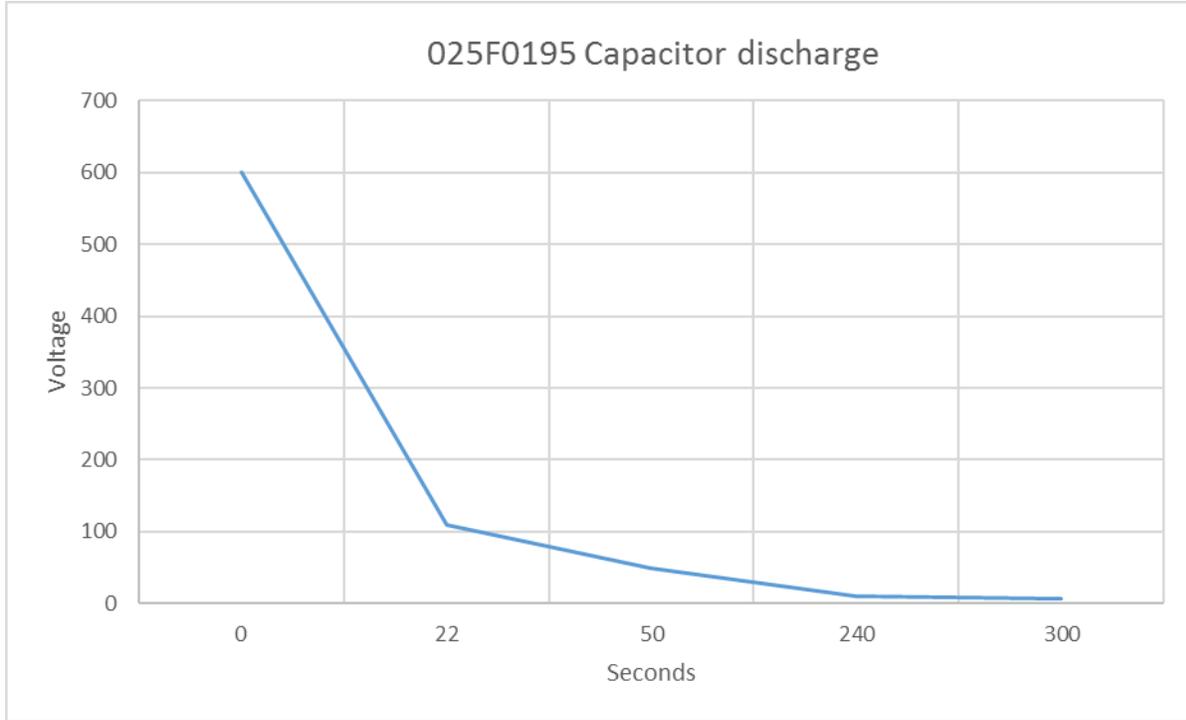
The graph above is a typical discharge rate of the bus capacitors after power has been removed with the initial charge of 600V. As shown, the relay RL1 will be open after 60 seconds.

Appendix C   Configurations

The following controller model numbers have been tested with the listed compressors:

025F0195
 SIERRA00072

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