Excerpt from

BRUSHLESS ELECTRIC MOTORS AND DIGITAL CONTROLS USER'S MANUAL (obsolete)

SERIES T161	**DIGITAL RACK MOUNT CONTROLLERS**
SERIES 160	**RACK MOUNT POWER SUPPLY**
SERIES 300A	**BRUSHLESS SERVO MOTOR**

This is a portion of a user's manual made available in segments on the website for the convenience of our customers. If you have questions or need additional information please contact us

This manual describes the functionality and features of the present version of the T161, 160 and 300A Product Family. Not all of the described features are available in previous versions of the T161, 160 and 300A.

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4. *COMPONENT DESCRIPTION AND SPECIFICATION*

This Section provides descriptions and specifications for the RMC Power Supply, the T161 Series Controllers, the B81318-001 Hand Held Terminal, the Encoder Simulator Option Card, and the 300A Series Motors.

4.1. Power Supply Description, Specifications

The power supply has the following features:

- Single or Three Phase A-C Operation
- Direct off-line 220 VAC Operation
- Soft Start (A-C Inrush Current Limiting)
- Integral Shunt Regulator
- Fast Bus Discharge
- Phase Loss Detection
- Provision for External Regen Resistor
- Regen Electronic Circuit Breaker
- Power Supply Fault Relay
- Diagnostic LED's

The major components of the power supply are indicated in Figure 4-1.

WARNING

Power supplies contain large capacitors that maintain high voltage on the DC+ to DC- terminals for several minutes after input power is removed if the regen resistor circuit is open (fuse blown or wiring open).
*Wait at least 5 minutes after power shutdown for capacitors to discharge. Using a multimeter, measure the DC BUS (at **X7** Pin #1 and #2) to ensure that it has been discharged. Failure to follow this procedure might result in serious personal injury.*

4.1.1. Diagnostic LED's

The status of the power supply may be monitored using the diagnostic LED indicators on the front panel as listed in Table 4-1.

4.1.2. Circuit Description

The power supply consists of four functional blocks:

- High voltage rectification and filtering
- Low voltage control power supply
- Shunt regulator circuit
- Monitoring and fault logic circuits

Figure 4-2 is a block diagram of the 160 Power Supply.

LED #	LED Color	Label	Condition Indicated
1	Green	BUS ACTIVE	Greater than 30 VDC is present on the high voltage DC bus.
2	Green	LOGIC VOLTAGE OK	The + 15, - 15, and + 5 VDC are present.
3	Red	REGEN FUSE BLOWN	The fuse protecting the regen resistor has opened.
4	Red	THERMAL FAULT	Baseplate over temperature
5	Red	DC BUS OVER VOLTAGE	DC Bus has exceeded 400 VDC.
6	Yellow	REGEN ACTIVE	The regen circuit is active because the bus voltage exceeds the regen cut-in threshold or a-c power has been lost and a fast bus discharge is occurring.
7	Red	LOSS OF PHASE	Phase loss or power loss on incoming AC mains.

TABLE 4-1. 160 POWER SUPPLY STATUS INDICATORS

4.1.2.1. High Voltage Rectification and Filtering

The a-c mains input is rectified by a three phase diode bridge and filtered by a large bank of electrolytic capacitors to generate a nominal 300 VDC supply at 25 amps. This high power 300 VDC supply is unregulated and will vary in direct proportion with the a-c mains input.

4.1.2.2. Low Voltage Control Power Supply

Control power for the logic circuits is generated by a fly back current mode converter. There is no isolation from the a-c mains provided by this supply.

4.1.2.3. Shunt Regulator Circuit

Rapid motor deceleration or an overhauling load creates a situation in which energy is regenerated back into the high voltage power supply. This regenerative energy will charge the power supply bus capacitors. To prevent capacitor over voltage a shunt regulator circuit senses when the bus voltage exceeds the regen cut-in voltage and via a regen transistor, switches a regen resistor across the d-c bus, (in shunt), to dissipate the regen energy. Hysteresis in the shunt regulator circuit keeps the regen circuit active until the bus voltage is reduced below the regen cut-out voltage. The frequency at which the regen circuit operates is dependent upon the magnitude of the regen energy. If the regen energy exceeds the capacity of the regen circuit, a higher capacity regen resistor must be used. The supply includes an internal regen resistor with 40 watt capacity. An optional external regen resistor with higher capacity can be utilized, as explained in Section 2.4.

An electronic circuit breaker protects the regen circuit against external short circuits and protects the regen resistor from exceeding its continuous rating. If the regen resistor continuous rating is exceeded the electronic circuit breaker disables the shunt regulator circuit. In this case, additional regen energy from the motor will cause the d-c bus voltage to increase until an over voltage fault occurs. Under this condition, the regen circuit is undersized for the application. Figure 4-3 provides energy vs. time curves for the electronic circuit breaker. A regen fuse is provided to protect the regen resistor in case of failure of the regen circuit electronics. A monitoring circuit provides a REGEN FUSE fault if the regen fuse blows. The regen electronic circuit breaker prevents nuisance tripping of the regen fuse.

4.1.2.4. Monitoring and Fault Logic

There are two fault outputs in the supply. The "Customer Fault Output" is relay K2 (4C1) capable of sinking or sourcing 1 amp and withstanding up to 75V. It is "closed" during normal operation and will be "open" to indicate a fault. The faults that are detected are Thermal Fault, Loss of Phase, Bus Over voltage, Regen Fuse Blown and Soft start. Note that a fault indication in the power supply will not stop the supply from operating, except that a blown regen fuse will not allow the DC bus relay K1 to close. This means that the DC bus will remain at 0VDC if the fuse is blown or missing when the unit is powered up. The fault output relay should be monitored by the customer and the system shut down in the event of a power supply fault. The Loss of Phase fault can only be read through this fault relay output.

The "PSF" bit, an open collector output, goes out to the back plane and to each of the controllers in the rack. It detects the same faults as the customer fault relay with the exception of Loss of Phase and Thermal Fault. If the PSF bit detects a fault the controllers disable. In the -007 and -008 models the soft start condition (i.e. powering up the DC bus from high voltage AC) causes a "PSF fault". This is done to prevent the controllers from enabling before the DC bus is fully charged. If the controllers were to be enabled during soft start, the DC bus would not get fully charged and at the end of the soft start period a hard start (i.e. very high inrush currents) would occur.

INTERNAL 40 WATTS	
POWER (WATTS)	**TIME (SECONDS)**
40	CONTINUOUS
50	90
100	15
200	6
300	4
500	2.5
1000	1.2

EXTERNAL 240 WATTS	
POWER (WATTS)	**TIME (SECONDS)**
240	CONTINUOUS
300	180
500	29
1000	9
1500	5
2000	4
2500	3
4000	1.8

TABLE 4.2 MODEL 160-007,008 POWER SUPPLY REGEN ELECTRONIC CIRCUIT BREAKER TRIP CHARACTERISTICS

4.1.3. Specifications

A-C Input Voltage	220 VAC ±15% 50/60 Hz
D-C Output Voltage	300 VDC No-Load Unregulated

	Three phase Operation	Single phase Operation
Continuous Output D-C Power		
With Cooling Fan	7.5 KW	2.5 KW
Without Cooling Fan	2.5 KW	0.8 KW

24 volt Input Power	
Voltage Range	20 Vdc min to 35 Vdc max
Power Requirements	1 amp per axis @ 24 volts
Inrush current	2 amps for 50 msec @ 24 volts
Regen Cut-in Voltage	380 VDC ±5%
Regen Hysteresis Voltage	7 VDC ±5%

	Internal 50Ω 40W Resistor	External 8.3Ω 240W[1] Resistor[2]
Peak Regen Power	2.8 kW	17 kW
Continuous Regen Power	40 W	240 W
Regen Fuse	ABC-3	ABC-15

[1]*In parallel with internal 50Ω55W resistor.*

Base plate Over temperature Trip Point	90°C ±5°C
Operating Temperature Range	0 - 55 °C ambient
Humidity	5% to 95% non-condensing
Altitude	3300 feet[5]

[5]*Derate output 2% per 1000 feet above 3300 feet.*

Weight	4.8 lb. (2.2 kg)

4.2. T161 Series Controllers Description, Specifications

Controllers have the following features:

- Sinusoidal Three Phase Drive
- Resolver Based System
- Microprocessor Based
- Digitally Tuned Current Loop
- Configuration Stored in Non-Volatile E^2PROM
- Programmable Velocity or Current Control
- Programmable Analog Test Points
- RS232 / RS485 Serial Port
- PC Set-up via "MOOGTERM" software
- 24 VDC Control Power Input (Option)
- Encoder Simulation (Option Card)

In addition, Controllers incorporate the following protection features:

- Watchdog Timer
- Logic Under voltage
- I-T Current Foldback
- Short Circuit
- Motor Over temperature
- Controller Over temperature
- Resolver Loss

The major components of the Controllers are indicated in Figure 4-4.

4.2.1. Diagnostic LED's

The status of the Controller may be monitored using the diagnostic LED indicators on the front panel as listed in Table 4-2.

LED Color	Label	Condition Indicated
Red	SYSTEM FAULT	A software or hardware fault has occurred. The specific fault can be determined by querying the controller via the communications interface.
Yellow	FOLD BACK ACTIVE	The continuous torque limit has been exceeded.
Green	ENABLE	Controller is enabled and ready to accept motion command.

TABLE 4-3. T161 SERIES CONTROLLER STATUS INDICATORS

4.2.2. Circuit Description

This description of the T161 series controller refers to Figure 4-5, the controller block diagram.

4.2.2.1. Logic Power Supply

Logic power for the control is generated in the model 160 power supply. This is delivered by way of the back plane to all RMC axes installed.

4.2.2.2. CPU Section

The microprocessor (CPU) used in the control is an 80C186. It interfaces to 16K of RAM, 128K of EPROM, EEPROM, A/D converter, D/A converter, watchdog timer, fault detection and display circuitry, and UART serial communication device. The CPU stores setup parameters in EEPROM so that they are available after power is removed and reapplied. It takes in the discrete enable input and the analog command input from the customer interface. Under the conditions of proper setup, no control faults, and valid enable, the CPU enables the output stage and provides the commutated phase current commands to drive the motor in either the torque controlled mode or the velocity controlled mode. One of these modes is selected by the user. The CPU accepts user setup information and provides status information via the UART serial interface. Faults are detected and processed by the CPU. A watchdog timer which has a time-out time of 2.5 milliseconds will disable the controller were the CPU to fail.

4.2.2.3. Analog to Digital Section

The analog command input has an input voltage level of +/- 10VDC. It is brought in to a differential amplifier. The choice is available in software to either use this command signal unfiltered or to use a low pass filter on the command. The filter has a -3dB point of 1KHz and an inband time delay of 360µsec. The command signals are converted by the A/D converter, a 12 bit converter.

The resolver excitation signal is sinusoidal at 3.0 KHz, 4VRMS, and can drive up to 100ma. The resolver SIN and COS feedback signals are expected to be at a 2VRMS level. They are brought in to differential amplifiers, filtered, and converted by the A/D converter.

4.2.2.4. Digital to Analog Section

The CPU outputs the properly commutated motor phase A and phase B current commands to the current loop through the D/A converter section. One customer programmable test point and one fixed test point are also provided by the D/A converter section.

4.2.2.5. Current Loop

The current loop takes the command signals from the D/A section and the motor phase current feedback signals and generates a closed loop current error signal which drives the PWM (pulse width modulation) stage. PWM is used to convert the analog current error into a digital command for the three phase inverter bridge. The setup parameters of the current loop are varied depending on the type of motor and controller size used. This motor specific information is contained in the MCO module and is provided to the current loop upon power up. The gate drive takes the digital current loop PWM commands and level and amplitude shifts them to an appropriate voltage to drive the 6 high voltage IGBT transistors in the inverter output bridge.

4.2.2.6. UART

The UART (universal asynchronous receiver/transmitter) is used to provide the CPU with communication information from the user and to provide the user with controller status information. Two modes of communication are available through the UART interface: RS232 and RS485. RS232 is a 3 wire standard computer serial interface for talking from one device (computer or terminal) to one other device (T161 Series Controller). RS485 is a 2 wire multidrop communication interface. Up to 32 communication nodes are supported (31 "slaves", i.e. T161 Series Controllers, and 1 "master", i.e. a PC). RS232 or RS485 is selected by the position of the jumpers L2 through L5. Installing the jumpers across L2,L3,andL5 will provide RS232 and connecting the jumper across L4 only will provide RS485.

4.2.3. Specifications

D-C Input Voltage 130 VDC - 370 VDC (310 VDC Nominal)

Output Current Ratings:

	RMS Amps Per Phase		Peak Amps Per Phase	
Model	Continuous	Peak (5 Sec)	Continuous	Peak (5 Sec)
T161-001	3	5	4.2	7.1
T161-002	5	10	7.1	14.2
T161-003	8	20	11.3	28.4
T161-004	12	40	16.9	56.8

Output Current Ripple Frequency

T161-001, -002 20 KHz T161-003, -004 10 KHz

Analog Input Command (Differential)

±10 Volts = CW/CCW Max. Speed (Velocity Mode)

±10 Volts = ± Peak Current (Torque Mode)

Input Impedance 22.3 KΩ

Analog Torque Limit Command (Differential)

0 to 10 Volts = 100 to 0% Torque Output

Input Impedance 44.2 KΩ

Enable Input

Torque/Velocity Select

Auto/Manual Mode

Group Auto/Manual Mode

Supply Voltage Range[1]	4.5 - 35 VDC
Input Impedance	2.0 KΩ Min.
Polarity	Current Activated.

Serial Interface

Type	RS232 or RS485
Baud Rate	9600
Parity	None
Data word	10 bit (7 data, 1 start, 2 stop, no parity)

Resolver Interface

Excitation Frequency	3.0 KHz
Excitation Output	4.0 V RMS @ 100 mA Max.
Sine/Cosine Return	2.0 V RMS 20 KΩ input impedance (differential)
Efficiency	>95%[2]
Velocity Loop Update Rate	2.5 KHz
Base plate Over temperature Trip Point	90°C ±5°C
Operating Temperature Range	0 - 55°C ambient
Humidity	5% to 95% non-condensing
Altitude	3300 feet[3]
Weight	
T161-001 through -003	5.0 lb. (2.3 kg)
T161-004	10.5 lb. (4.8 kg)

[1] *User must supply isolated power source.*

[2] *Rated Continuous Current, 50% Rated Output Voltage.*

[3] *Derate output 2% per 1000 feet above 3300 feet.*

4.3. B81318-001 Hand Held Terminal (Option) Description, Specifications

The Moog B81318-001 hand held terminal, shown pictorially in Figure 4-6, is an optional accessory product which can be used in lieu of a terminal for controller set-up and monitoring. The hand held terminal is supplied with a coiled cable which has a DE9P connector that mates with the T161 Series Controller X6 communications connector.

4.3.1. Specifications

Weight	8 ounces (230 grams)
Storage Temperature	-20°C to 70°C
Operating Temperature	0°C to 50°C
Relative Humidity	10% to 90% Non-Condensing
Character Set	US ASCII, upper and lower case with two break functions
Interface	RS232C
Case	Molded, High Impact ABS with retractable hanger
Keypad	45-key tactile
Display	4 row by 20 character LCD with 5 by 7 character font
Power Requirement	30 mAmps max., 5 VDC ±5% (Supplied by T161 Series Controller)
Speaker	Audible Key Click, Bell and Alert

4.4. Encoder Simulator Option Card Description, Specifications

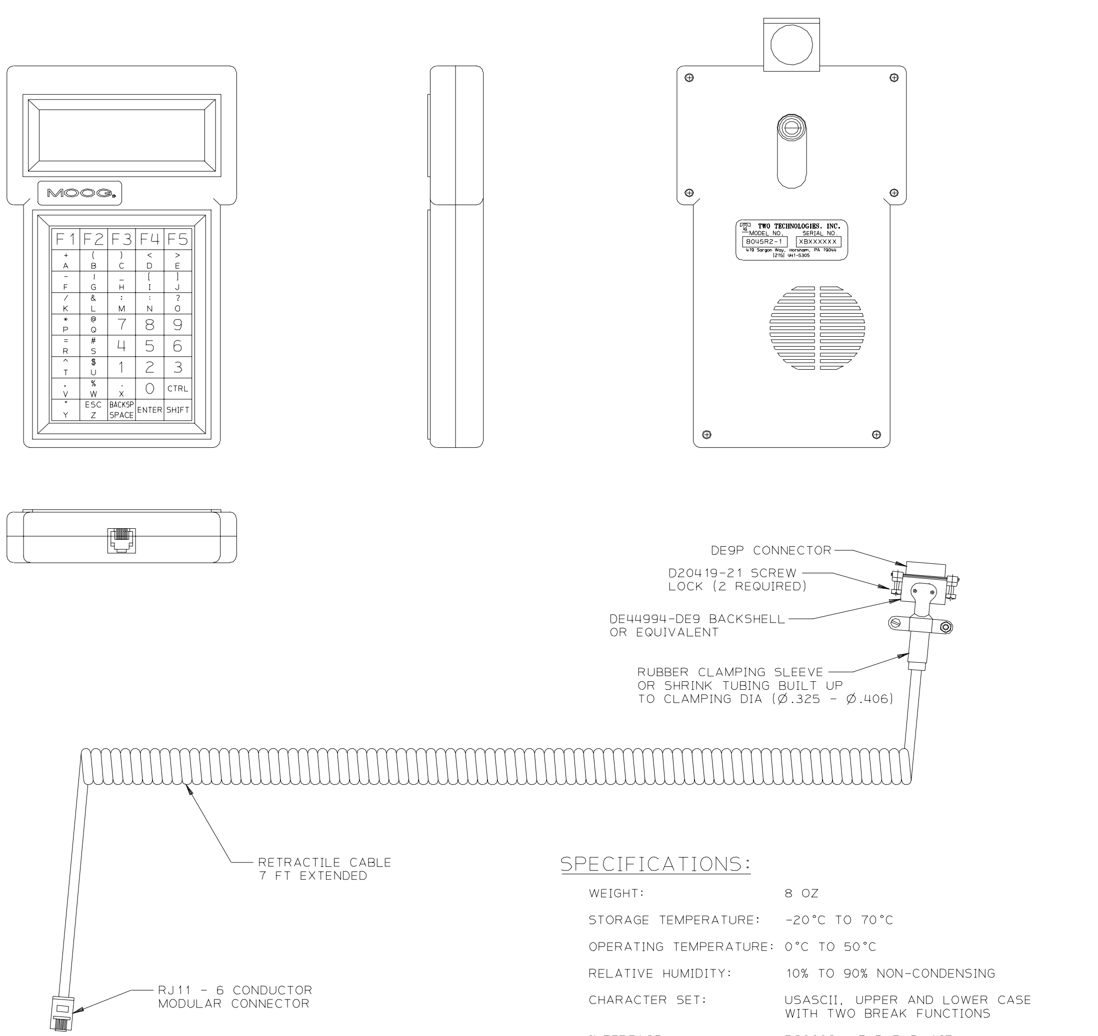
The Encoder Simulator Option Card has the following features:

- Emulates Rotary Incremental Encoders
- Line Count and Marker Width selectable by jumper position.
- Ability to read Digital Position information through User Interface Software
- Error status monitored by User Interface
- RS-422 Differential Incremental Encoder Outputs (outputs are optically isolated)
- Customer supplied (V external) input is polarity protected
- Buffered Analog Velocity Output (Option - Consult Factory)

4.4.1. Circuit Description

The Encoder Simulator emulates the functionality of a rotary incremental encoder. The differential outputs of the Encoder Simulator are A, A/, B, B/, MARKER and MARKER/.

The design is based on a Resolver to Digital (R/D) converter to generate rotor position data. The position data is then multiplexed and converted into optically isolated and buffered incremental encoder quadrature outputs. Power for the isolated outputs is provided by a user supplied +5 VDC power supply.



SPECIFICATIONS:

WEIGHT:	8 OZ
STORAGE TEMPERATURE:	-20°C TO 70°C
OPERATING TEMPERATURE:	0°C TO 50°C
RELATIVE HUMIDITY:	10% TO 90% NON-CONDENSING
CHARACTER SET:	USASCII, UPPER AND LOWER CASE WITH TWO BREAK FUNCTIONS
INTERFACE:	RS232C...TXD, RXD WITH HARDWARE HANDSHAKE OR RS422...+TXD, -TXD, +RXD, -RXD
COMMUNICATION PARAMETERS:	300-19200 BAUD 7 OR 8 DATA BITS 1 OR 2 STOP BITS ODD, EVEN, MARK, SPACE, IGNORE OR NO PARITY XON/XOFF
CASE:	MOLDED, HIGH IMPACT ABS WITH RETRACTABLE HANGER
KEYPAD:	45-KEY TACTILE, WITH A TOTAL OF 10 USER PROGRAMABLE FUNCTION KEYS
DIPLAY:	4-ROW BY 20 CHARACTER TRANSREFLECTIVE LCD WITH 5 BY 7 CHARACTER FONT
POWER REQUIREMENTS:	30 MILLAMPERES MAXIMUM, REGULATED 5 VOLTS DC ±5%
SPEAKER:	AUDIBLE KEY CLICK, BELL & ALERT

FIGURE 4-1. B81318-001 HAND HELD TERMINAL

The Built In Test (BIT) output of the R/D converter is monitored. Logic 0 for BIT condition indicates ±100 LSBs of error. Causes of BIT error are loss of signal inputs or loss of resolver reference. When this occurs, the Encoder Simulator outputs will go to a known state.

Figure 4-7 is a block diagram of the Encoder Simulation option card.

4.4.1.1. A and B Outputs

The A and B outputs are in quadrature, i.e. B will lead A by 90° when the motor is rotating clockwise (CW) as viewed looking at the motor front mounting plate and A will lead B by 90° when the motor is rotating counterclockwise (CCW). The phase relationship of A and B can be used to determine motor direction.

Since the Encoder Simulator outputs are in true quadrature, the ripple associated with the duty cycle variation of a normal encoder is avoided when using X2 or X4 counting schemes.

The resolution of the Encoder Simulator, in pulses per revolution (ppr), is selectable from 128 ppr to 16384 ppr. The factory default resolution is 256 ppr. The allowable motor operating speed range is reduced at higher Encoder Simulator resolutions as indicated in Table 4-3.

R/D Resolution (Bits)	**Line Count (Pulse Per Rev)**	**Motor Speed Range (RPM)**
16	16384	0-1400
16	8192	0-1400
14	4096	0-6000
14	2048	0-6000
12	1024	0-15000
12	512	0-15000
10	**256**	**0-15000**
10	128	0-15000

TABLE 4-4. ENCODER SIMULATOR CONFIGURATION OPTIONS

4.4.1.2. Marker Pulse

The MARKER, or INDEX pulse, is used to indicate a reference point within one mechanical revolution of the motor shaft.

NOTE

The marker pulse is not referenced to the key of the motor shaft or housing. The pulse is set at an arbitrary position that is determined by the resolver adjustment setting used for motor commutation. This is a factory setting and not user adjustable.

The electrical width of the MARKER pulse is selectable in pulse widths of 90°, 180° or 360°, where 360° is the entire width of one A and B encoder cycle. The factory default configuration is 90° marker width.

The output wave forms for the Encoder Simulator are shown in Figure 4-8.

4.4.2. Specifications

Resolver Reference Input	Differential ±10V max.
Signal Inputs (Sine+, Sine-, Cosine+, Cosine-)	Differential 2 Vrms ±15%
Input Power Requirements[1]	5 VDC ±5%, 200 mA max.

[1]*User must supply isolated power source.*

Dynamic Characteristics (Line Count Selection vs. Bandwidth based on 5KHz Resolver Reference):

Line Count Selection (PPR)	3 dB Closed Loop Bandwidth (Hz)
16384, 8192	288
4096, 2048	564
1024, 512	851
256	851

Digital Outputs A, A/, B, B/, MARKER and MARKER/

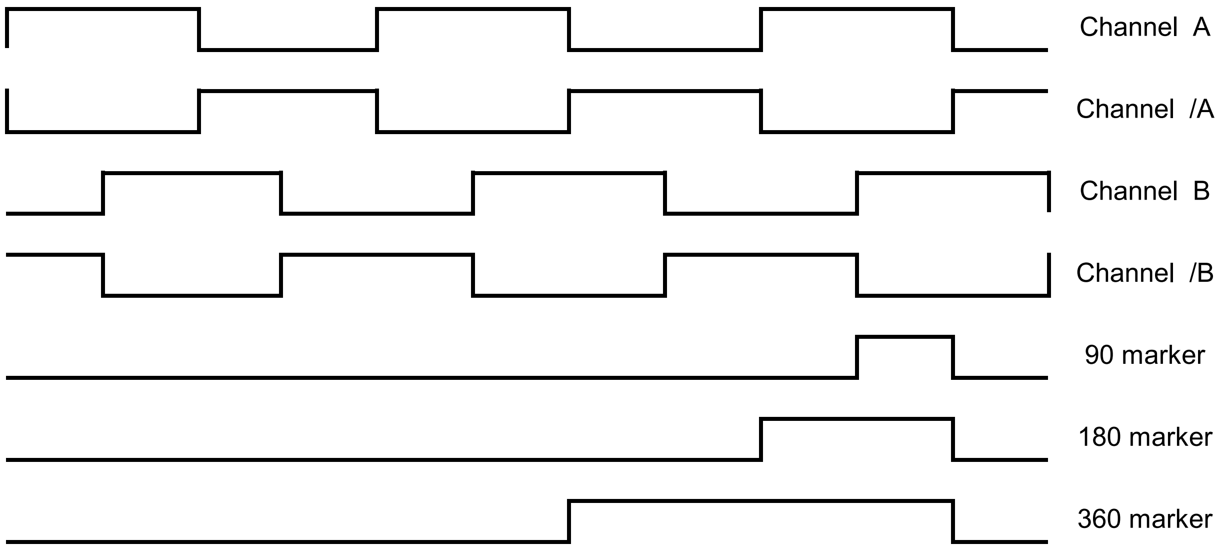
Optically Isolated RS-422 Differential

Outputs capable of driving 100Ω terminated loads

Output ' Logic High ' Voltage (Voh)	2.5V min.
Output ' Logic Low ' Voltage (Vol)	0.5V max.

Operating Temperature Range 0-55°C ambient

COUNTERCLOCKWISE ROTATION



CLOCKWISE ROTATION

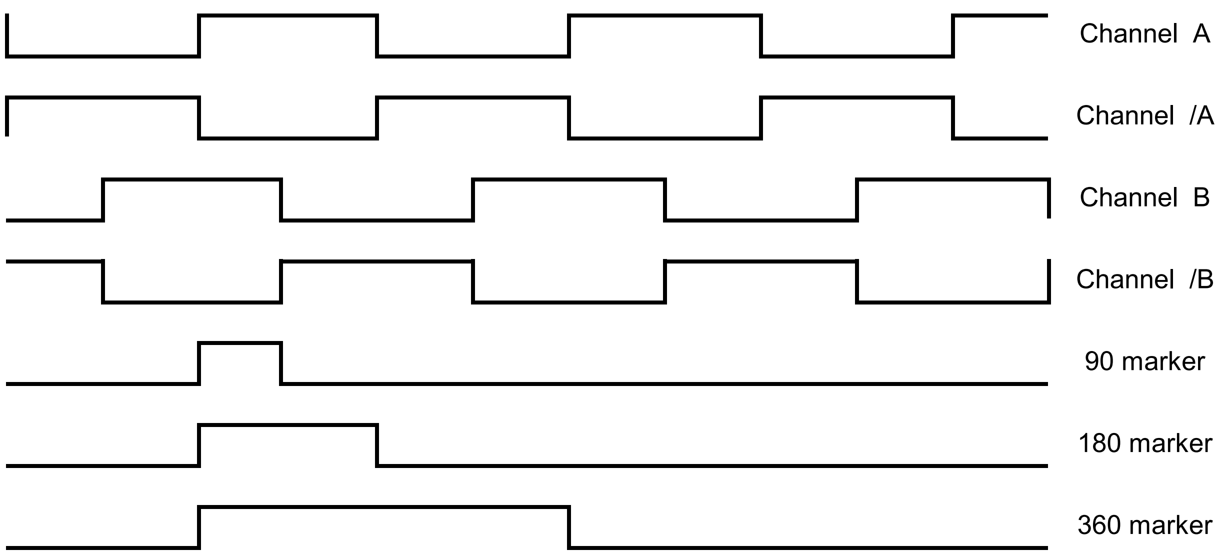


FIGURE 4-2. ENCODER SIMULATOR OPTION OUTPUT WAVE FORMS

4.5. Series 300A Motors Description, Specifications

NOTE

Refer to Section 2.5, Motor Installation, for information on axial and radial load capability, bearing life, mounting screws and motor-to-load coupling.

4.5.1. Description

Motors are permanent magnet brushless with an integral brushless resolver for position feedback.

The 303 through 306 frame size motors can be face or flange mounted.

All motors incorporate a thermostat or thermistor for thermal protection.

Motors are available with an optional static holding brake.

4.5.2. Specifications

Torque ratings are at 40°C ambient mounted on a 12 × 12 × 0.5 inch (30 × 30 × 1.25 cm) aluminum heat sink. Ratings are shown in Table 4-4 and Characteristics are shown in Table 4-5 for standard motors.

MODEL	CONTINUOUS TORQUE, T_c		NO LOAD SPEED	PEAK TORQUE, T_p	
	lb.	NM	rpm	lb. in.	NM
303-029A	5.5	.62	8600	17	1.92
303-030A	15	1.69	10900	60	6.67
304-111A	12	1.36	7400	50	5.65
304-121A	28	3.16	5650	95	10.73
304-131A	48	5.42	4600	190	21.47
304-141A	73	8.25	2740	380	42.93
304-151A	94	10.62	2675	550	62.15
305-111A	51	5.76	5400	145	16.38
305-121A	74	8.36	4450	220	24.86

TABLE 4- 5. STANDARD SERIES 300A MOTOR RATINGS

MODEL	TORQUE CONSTANT, K_t		Inertia, J_m		Mech. Time Constant, τ_m	Elect Time Constant, τ_e	Weight	
	lb. in./amp	NM/amp	$lbin.s^2*10^{-3}$	$kg\text{-}m^2*10^{-4}$	msec	msec	LB	kg
303-029A	3.53	.40	.16	.18	2.33	0.64	3.0	1.4
303-030A	2.78	.31	.37	.42	1.14	1.24	4.0	1.8
304-111A	4.13	.47	.9	1.0	2.50	1.20	6.4	2.9
304-121A	5.39	.61	1.6	1.8	1.50	1.91	7.5	3.4
304-131A	6.65	.75	2.7	3.1	1.10	2.58	9.7	4.4
304-141A	11.24	1.27	5.0	5.6	1.10	2.70	13.7	6.2
304-151A	11.51	1.30	7.3	8.2	1.00	2.75	17.8	8.1
305-111A	5.61	.63	5.2	5.9	1.70	4.20	15.6	7.1
305-121A	6.82	0.77	7.3	8.2	1.20	5.40	18.2	8.3

TABLE 4-6. STANDARD SERIES 300A MOTOR CHARACTERISTICS

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