CURTIS

Manual

Model **1355**

5x High Current Output
CANopen Slave Soft Starter Module

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Read Instructions Carefully!

53220, Rev A 7/5/15

The Curtis Difference

You feel it when you drive it

CONTENTS

FIGURES

TABLES

1 OVERVIEW

The Curtis Model 1355 is a 5x high-current half bridge output module for soft start of electrical motors. The 1355 is available with either three full actuator outputs or six digital inputs.

The module is designed to give it the flexibility to be used in a variety of sweepers/scrubbers. Typically M1–M3 are used to drive the brushed permanent magnet motors that power the scrubbing brush pads, and M4–M5 are used to drive the series-wound DC vacuum motors used to recover the used cleaning solution from the floor.

The housing is designed to meet the difficult environment seen in material handling and outdoor equipment. This water-tight design can survive high shock, vibration, and dust.

Fig. 1 *Curtis 1355 CANopen slave soft starter module.*

Features include:

✓ Programmable DC nominal supply: 24V, 36V, or 48V

✓ Five high-current half bridge drivers for motor loads (M1–M5)

✓ 3A driver output for a main (line) contactor, with overload protection

✓ KSI input

✓ CAN bus port

✓ Threaded busbars for B+, B-, and the five motor loads

✓ 14-pin AMPSEAL connector for low-power loads (actuator loads, CAN bus, KSI, I/O, etc.)

More Features ☞

- ✓ Protection from short circuits, under/over voltage, and reverse polarity
- ✓ Capacitor bank pre-charge circuit prevents arcing
- ✓ Field upgradeable firmware
- ✓ IP65 sealing
- ✓ Externally viewable dual power/status LED clearly flash the fault code
- ✓ Serial communication port for Curtis 1311/1313/1314 programmers
- ✓ *1355-X001:* three full bridge drivers for linear actuators, typically used to lift/lower the brush deck and the squeegee and control the detergent delivery pump
- ✓ *1355-X101:* six digital inputs; Digital Input 6 can be used as an interlock.

SOFT START MODE

Soft Start mode provides a linear acceleration ramp from 0V to full voltage (pure DC, no PWM), and linear deceleration from full voltage to 0V. In this way, it can reduce the starting current of the motor, and also can effectively mitigate the surging problem of the inertia system when stopping.

PWM MODE

If Soft Start mode is not desired, M1–M5 can drive motors at PWM% within the 1-hour rating.

PARALLEL MODE (M4/M5) and H-BRIDGE MODE (M1/M2)

The M4 and M5 outputs can be used in parallel to drive a single large motor load for vacuum. The 1355 uses the parameters of M4 to control the motor.

The M1 and M2 outputs can provide bi-directional motor control by connecting one motor load in an H-bridge configuration. The 1355 uses the parameters of M1 to control the motor.

Both Parallel mode and H-Bridge mode can run in either Soft Start mode or PWM mode.

Familiarity with your Curtis 1355 module will help you install and operate it properly. We encourage you to read this manual carefully. If you have questions, please contact the Curtis office nearest you.

2

INSTALLATION AND WIRING

MOUNTING THE MODULE

The outline and mounting hole dimensions for the 1355 module are shown in Figure 2. The module should be securely mounted to the vehicle using four M5 screws.

CAUTION

Care should be taken to prevent contaminating the connector area before the mating14-pin connector is installed. Once the system is plugged together, the 1355 meets the IP65 requirements for environmental protection against dust and water. Nevertheless, in order to prevent external corrosion and leakage paths from developing, the mounting location should be carefully chosen to keep the module as clean and dry as possible.

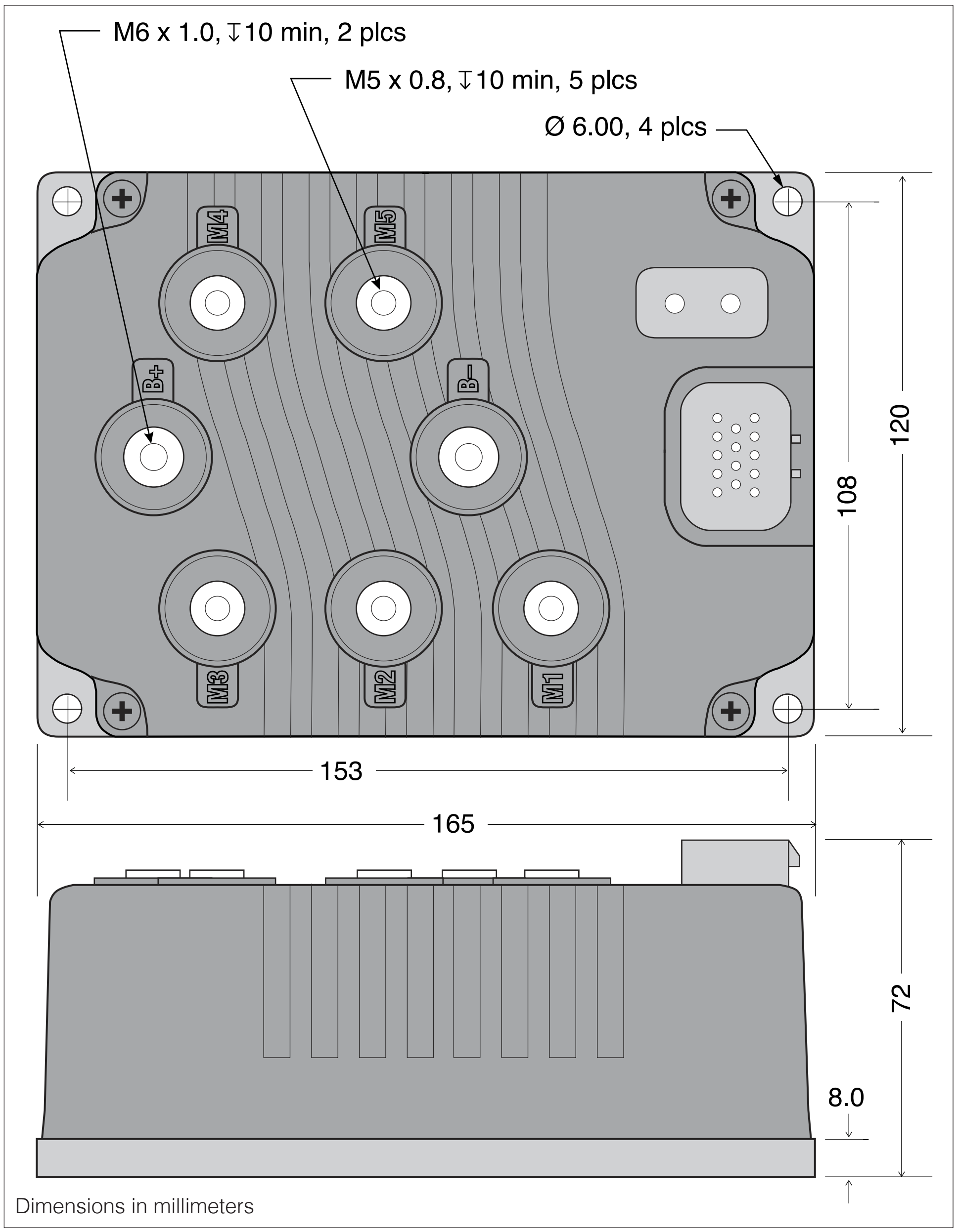


Fig. 2 *Mounting dimensions, Curtis 1355 soft starter module.*

If the outputs will be used at or near their maximum ratings, it is recommended that the module be mounted to a good heatsinking surface, such as an aluminum plate.

You will need to take steps during the design and development of your end product to ensure that its EMC performance complies with applicable regulations; suggestions are presented in Appendix A.

The 1355 contains **ESD-sensitive components**. Use appropriate precautions in connecting, disconnecting, and handling the module. See installation suggestions in Appendix A for protecting the module from ESD damage.

CAUTION

Working on electrical systems is potentially dangerous. You should protect yourself against uncontrolled operation, high current arcs, and outgassing from lead acid batteries:

UNCONTROLLED OPERATION — Some conditions could cause the motor to run out of control. Disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the motor control circuitry.

HIGH CURRENT ARCS — Batteries can supply very high power, and arcing can occur if they are short circuited. Always open the battery circuit before working on the motor control circuit. Wear safety glasses, and use properly insulated tools to prevent shorts.

LEAD ACID BATTERIES — Charging or discharging generates hydrogen gas, which can build up in and around the batteries. Follow the battery manufacturer's safety recommendations. Wear safety glasses.

HIGH POWER CONNECTIONS

The **B+** and **B-** connections are via female-threaded M6 busbars; the suggested torque in 5.5 N·m. The five motor outputs (**M1**, **M2**, **M3**, **M4**, **M5**) are connected via female-threaded M5 busbars; the suggested tightening torque is 3.5 N·m.

The **B+** and **B-** cables should be run close to each other between the module and the battery. For best noise immunity the cables should not run across the center section of the module.

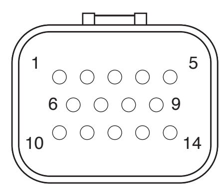
M1 and **M2** can be used together to provide bi-directional motor control by connecting one motor load across these two outputs, making a full bridge configuration. The motor is controlled by the M1 programable parameters.

M4 and **M5** can be used together as parallel outputs to drive a single large motor load for vacuum operation.

M1–M5 are protected from both over and under temperature; warnings are issued when the temperature reaches the cutback threshold and output is disabled when the temperature reaches the cutoff threshold.

LOW POWER CONNECTIONS

All connections are made through the 14-pin AMPSEAL connector. The low power connector will mate to a 14-pin AMPSEAL wire header.



The module's plastic cover features a molded-in receptacle that mates with a standard 14-pin AMPSEAL housing and includes keying features to prevent incorrect insertion.The connector will provide a proper seal and latch for the off-the-shelf AMPSEAL wire header/plug. **Note that the 1355's pins are not sealed until the mating connector is fully engaged and locked.**

The 14 individual pins are characterized in Table 1, for the three actuator model (1355-X001) and the six digital input model 1355-X101).

Table 1 Connector Pinout

PIN	1355-X001	1355-X101
1	Actuator 2B	Digital Input 1
2	Main Contactor Driver	Main Contactor Driver
3	CAN L	CAN L
4	CAN H	CAN H
5	+15V	+15V
6	Actuator 2A	Digital Input 2
7	Serial Rx	Serial Rx
8	Serial Tx	Serial Tx
9	KSI	KSI
10	Actuator 3B	Digital Input 3
11	Actuator 3A	Digital Input 4
12	B-	B-
13	Actuator 1B	Digital Input 5
14	Actuator 1A	Digital Input 6 (Interlock)

The pins shared by both models are described below. The remaining pins (1, 6, 10, 11, 13, 14) are model-specific and are described below the individual wiring diagrams.

Main Contactor Driver *(pin 2)*

This is a low side driver to switch the main contactor coil. The output is switched On after KSI is closed and all power on seft-tests have been completed. It will open in the event of some severe faults in the 1355 module.

CAN L/H *(pins 3, 4)*

The 1355 is configured to function as a CAN slave only. A CAN master can read all inputs and outputs, monitor values and error codes, control all outputs, and set parameter values. There is no end-of-line termination resistor built into the module; if the 1355 is placed at the end of the communication lines, an external 120 Ω ½ W resistor must be added across the lines.

The 1355 will be controlled by two single 8 byte CAN PDOs and will return two single 8 byte PDOs over the CANopen protocol. SDOs can be sent to program various settings and features within the module.

The following CAN status messages are transmitted: actual current, overload warning, overload trip, over current, motor open fault, motor short fault, etc.

The following CAN commands are received: On, Off, % PWM, current limit value, overload time value, etc.

CAN wiring should be kept away from the high current cables and cross it at right angles when necessary.

+15V and GND *(pins 5, 12)*

The +15V power supply for the programmer provides short circuit protection; the maximum output is 60 mA. The ground at pin 12 completes the programmer circuit.

Serial Rx/Tx *(pins 7, 8)*

These provide the serial receive and transmit data channels for the programmer.

KSI *(pin 9)*

The KSI input turns the 1355 on and off via the vehicle's keyswitch. The internal DC/DC has 0.51 A current limit protection, and a TVS clamps the KSI input in the event of over voltage.

WIRING: BASIC CONFIGURATION

Basic wiring diagrams are shown in Figure 3a (for the actuator models) and in Figure 3b (for the digital input models).

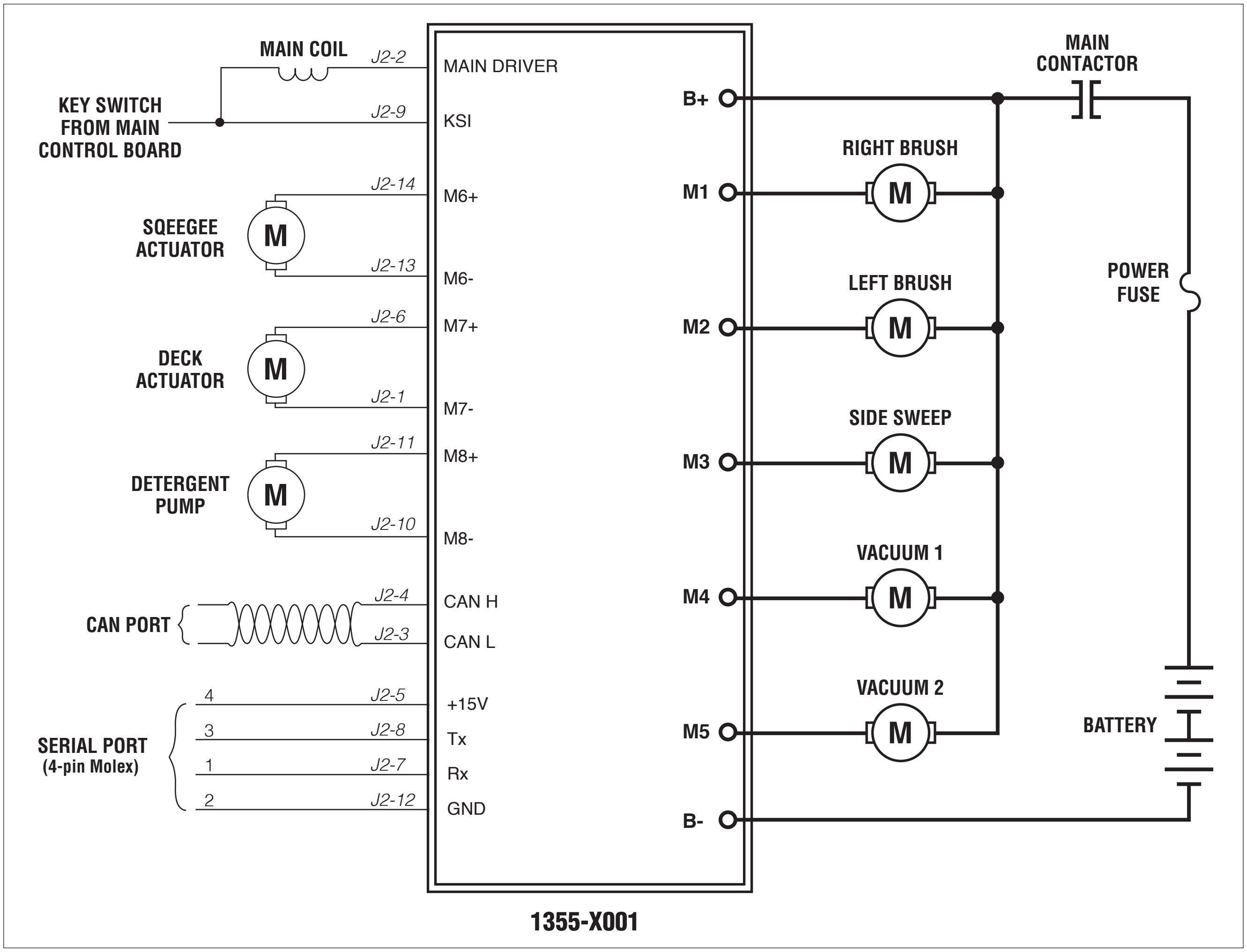


Fig. 3a *Basic wiring diagram, Curtis 1355-X001 module.*

1355-X001 Actuator Outputs *(pins 1, 6, 10, 11, 13, 14)*

Three full bridge linear actuator drivers can be used to lift/lower the brush deck and the squeegee, and control the detergent delivery pump with control logic from the CAN master.

100% PWM (pure DC) is not required; 0–95% PWM modulation is acceptable.

Stall Current Limit is programmable from 2.0 to 10.0 A. The actuator will be stopped if a large increase of output current is detected. It is not possible to operate the motor in the stalled direction until the actuator is first operated in the opposite direction.

The Stall Current Debounce Time is programmable from 0.0 to 5.0 seconds. This allows for high start-up currents and momentary overloads.

Accel/Decel is programmable from 0.1 to 2.0 seconds.

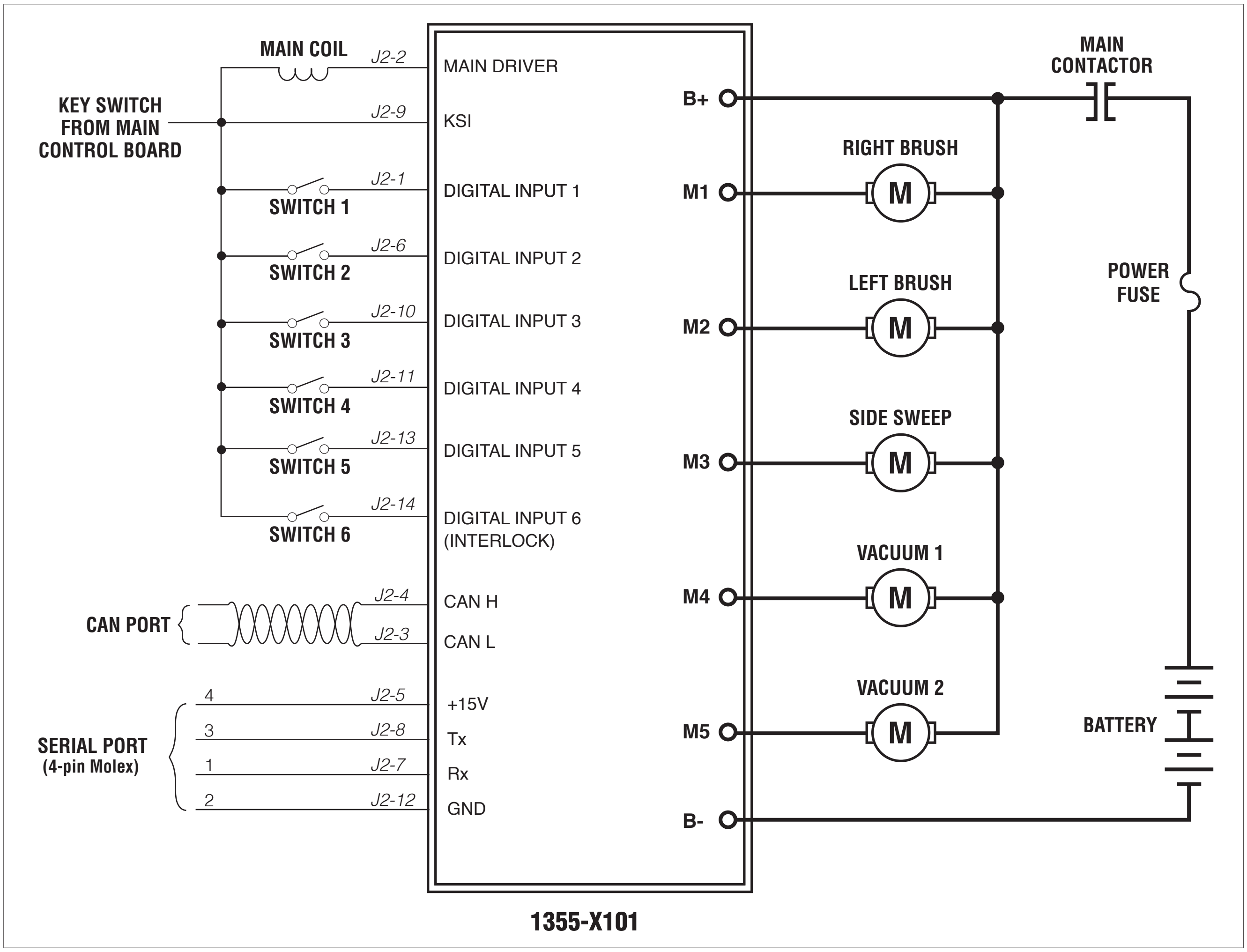


Fig. 3b *Basic wiring diagram, Curtis 1355-X101 module.*

1355-X101 Digital Inputs *(pins 1, 6, 10, 11, 13, 14)*

The six digital inputs can be programmed as remote inputs from CAN or as command switches via a programmer or over the CAN bus (SDO).

Input voltage range:
- 1355-4101 0–60 V
- 1355-5101 0–80 V.

Sink current:
- 1355-4101 3 mA at 60 V
- 1355-5101 3 mA at 80 V.

High level threshold: >10 V.

Pin 14 can be used as a digital input or as an interlock. When it is used as an interlock, this pin provides a second enable input such as a seat switch, a pedal switch, or a charger inhibit.

3 PROGRAMMER MENUS

The Curtis handheld 1311/1313 programmer or 1314 PC programming station can be used to adjust the programmable parameters, to read various monitored values, and to access fault information. For information on the programmers, see Appendix B.

Program Menus

The programmable parameters are arranged in menus, as shown in Table 2.

Table 2 Program Menus: 1311/1313/1314 Programmer

CONFIGURATION .... p. 11
- Nominal Voltage
- Overvoltage Warning Range
- Undervoltage Warning Range

MAIN CONTACTOR .... p. 11
- Contactor Control
- Pull In Voltage
- Holding Voltage
- Main Contactor Current Limit

INTERLOCK[b] .... p. 12
- Interlock Type[b]
- Startup Lockout Type[b]
- Sequence Delay[b]

M1–M5 .... p. 13
- Enable
- Current Limit
- Regen Current Limit
- Motor Open Current
- Accel
- Decel
- PWM Demand
- Overload Time
- Controlled By[b]
- Inhibited By[b]
- Output Off Delay[b]

ACTUATOR 1 – ACTUATOR 3[a] .... p. 14
- Enable[a]
- Stall Current Limit[a]
- Stall Current Debounce[a]
- Accel[a]
- Decel[a]

MODE .... p. 15
- Operation Mode[b]
- M1 PWM Mode
- M2 PWM Mode
- M3 PWM Mode
- M4 PWM Mode
- M5 PWM Mode
- M1 M2 H Bridge Mode
- M4 M5 Parallel Mode
- M1 M2 H Bridge Direction Input[b]

CAN INTERFACE .... p. 16
- Node ID
- Baud Rate
- Heartbeat Rate
- PDO Timeout

MISC[b] .... p. 16
- Digital Input 1 Normally Closed[b]
- Digital Input 2 Normally Closed[b]
- Digital Input 3 Normally Closed[b]
- Digital Input 4 Normally Closed[b]
- Digital Input 5 Normally Closed[b]
- Digital Input 6 Normally Closed[b]

[a] 1355-X001 only
[b] 1355-X101 only

CONFIGURATION MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Nominal Voltage	24.0–36.0 V 36.0–48.0 V	Sets the nominal voltage. 24.0–36.0 V for the 1355-4X01. 36.0–48.0 V for the 1355-5X01.
Overvoltage Warning Range	2.0–14.0 V	Sets the allowed voltage above the nominal voltage. When the capacitor bank voltage exceeds (Nominal Voltage + Overvoltage Warning Range), an Overvoltage Warning message is issued on the CAN bus and programmer.
Undervoltage Warning Range	2.0–14.0 V	Sets the allowed voltage below the nominal voltage. When the capacitor bank voltage drops below (Nominal Voltage - Undervoltage Warning Range), an Undervoltage Warning message is issued on the CAN bus and programmer.

MAIN CONTACTOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Contactor Control	On/Off	When programmed On, the 1355 controls the main contactor. When programmed Off, the main contactor is controlled by an external device.
Pull In Voltage	0–100 %	This parameter allows a high initial voltage when the main contactor first turns on, thus ensuring contactor closure. After 1 second, this peak voltage drops to the contactor holding voltage.
Holding Voltage	0–100 %	This parameter allows a reduced average voltage to be applied to the contactor coil once it has closed. This parameter must be set high enough to hold the contactor closed under all shock and vibration conditions the vehicle will be subjected to.
Main Contactor Current Limit	150–250 A	This parameter limits the max current on the contactor. If the current is higher than the programmed limit, the 1355 will limit the current of all the outputs so as to bring the main contactor current below its allowed limit. Meanwhile, the 1355 will report the fault on the CAN bus and programmer.

INTERLOCK MENU *(1355-X101 only)*

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Interlock Type	0–1	Selects the interlock type. 0 = Interlock turns on with Digital Input 6. 1 = Interlock turns on with KSI.
Startup Lockout Type	0–2	Selects the startup lockout type. 0 = No startup lockout. 1 = KSI-type startup lockout. To start the motors, KSI must be turned on before a startup request is received. Controller operation will be disabled immediately if the startup request is active before KSI is enabled, and a sequence fault will be declared. If the startup request is received before interlock switch On but after KSI On, the motor will accelerate to the requested speed as soon as interlock switch is closed. 2 = Interlock-type startup lockout. To start the motors, the interlock must be turned on before receiving a startup request. Controller operation will be disabled immediately if the startup request is active before the interlock switch is closed, and a sequence fault will be declared. Normal operation is restored after a startup lockout by reapplying the startup request in the correct sequence.
Sequence Delay	0.0–5.0 s	Sets the PWM output shutoff delay after the interlock switch is turned off.

M1 — M5 MENU *		
PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enable	On / Off	This parameter enables/disables the driver output and fault check. Note: Some severe faults, such as motor short and current sensor fault, will still be checked even when this parameter is disabled.
Current Limit	10 – 100 A *(24–36V models)* 10 – 70 A *(36–48V models)*	Sets the maximum current for the driver.
Regen Current Limit	10 – 100 A *(24–36V models)* 10 – 70 A *(36–48V models)*	Sets the maximum current for the driver when operating in regen mode.
Motor Open Current	0.0 – 10.0 A	Sets the minimum output current for this driver, below which a motor open fault is declared when the motor is running.
Accel	0.1 – 2.0 s	Sets the rate (in seconds) at which the driver output accelerates from zero to 100% PWM; see Figure 4.
Decel	0.1 – 2.0 s	Sets the rate (in seconds) at which the driver output decelerates from 100% PWM to zero.
PWM Demand	0 – 100 %	Sets the requested PWM when operating in PWM mode.
Overload Time	1 – 20 s	During current limiting, the Overload Trip timer Increases. If the timer exceeds the Overload Time, output will be shut down.
Controlled By *(1355-X101 only)*	0 – 6	This parameter defines which digital input will turn the driver. 0 = driver not controlled by any digital input. 1 – 6 = driver controlled by digital input 1 – 6.
Inhibited By *(1355-X101 only)*	0 – 6	This parameter defines which digital input will inhibit the driver. 0 = driver not inhibited by any digital input. 1 – 6 = driver inhibited by digital input 1 – 6.
Output Off Delay	0.0 – 30.0 s	The PWM will be shut off after the programmed Output Off Delay time expires following a stop command.

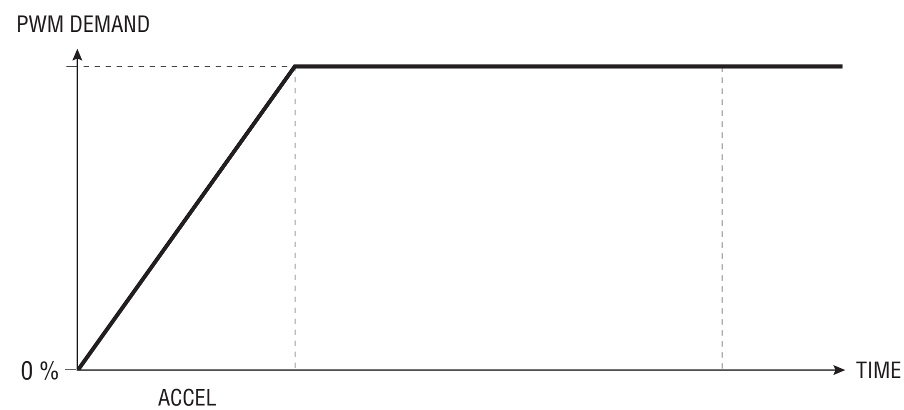
* This menu is repeated for each of the five motor drivers.

ACTUATOR 1 — ACTUATOR 3 MENU *(1355-X001 only)* *

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Enable	On / Off	This parameter enables/disables the actuator output and fault check. Note: Some severe faults, such as motor short and current sensor fault, will still be checked even when this parameter is disabled.
Stall Current Limit	2 – 10 A	Sets the maximum stall current for this actuator.
Stall Current Debounce	0.0 – 5.0 s	This parameter allows a high startup current and momentary overload. If the Stall timer exceeds the programmed debounce time, a stall fault is declared. It is not possible to operate the motor in the stalled direction until the actuator is first operated in the opposite direction.
Accel	0.1 – 2.0 s	Sets the rate (in seconds) at which the actuator output accelerates from zero to 100% PWM; see Figure 4.
Decel	0.1 – 2.0 s	Sets the rate (in seconds) at which the actuator decelerates.

* This menu is repeated for each of the three actuators.

Fig. 4 *Driver acceleration.*



PWM accelerates from 0% to the programmed PWM Demand parameter at the rate set by the Mx Accel or ActuatorX Accel parameters, and keeps that PWM setting. The Accel parameters can be adjusted (over the CAN bus or with a Curtis programer) from 0.1 to 2.0 seconds.

Note: In Soft Start mode the PWM Demand is not programmed and is always 100%.

MODE MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Operation Mode *(1355-X101 only)*	0–1	Defines whether the 1355 will be independent of the CAN system or be a CAN slave. 0 = Independent mode. 1 = CAN Slave mode.
M1 PWM Mode	On/Off	Determines whether the motor will run in PWM mode or in Soft Start mode. On = PWM mode. Off = Soft Start mode.
M2 PWM Mode	On/Off	Determines whether the motor will run in PWM mode or in Soft Start mode. On = PWM mode. Off = Soft Start mode.
M3 PWM Mode	On/Off	Determines whether the motor will run in PWM mode or in Soft Start mode. On = PWM mode. Off = Soft Start mode.
M4 PWM Mode	On/Off	Determines whether the motor will run in PWM mode or in Soft Start mode. On = PWM mode. Off = Soft Start mode.
M5 PWM Mode	On/Off	Determines whether the motor will run in PWM mode or in Soft Start mode. On = PWM mode. Off = Soft Start mode.
M1 M2 H Bridge Mode	On/Off	Determines whether H Bridge mode is active. On = H Bridge mode active. Off = H Bridge mode inactive.
M4 M5 Parallel Mode	On/Off	Determines whether Parallel mode is active. On = Parallel mode active. Off = Parallel mode inactive.
M1 M2 H Bridge Direction Input *(1355-X101 only)*	1–6	Selects the digital input that will be the direction command for the M1 M2 H bridge. When the selected input is On, the motor will run forward. When the selected input is Off, the motor will run in reverse. This parameter is ignored when the 1355 is working in CAN Slave mode.

CAN INTERFACE MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Node ID	1–127	Sets the Node ID of the 1355 CANopen slave system. Must cycle KSI or send an NMT RESET 1355 or an NMT RESET CAN for the new ID to take full effect.
Baud Rate	0–2	Sets the CAN bus baud rate. 0 = 125 kbps. 1 = 250 kbps. 2 = 500 kbps. Must cycle KSI or send an NMT RESET 1355 or an NMT RESET CAN for the new rate to take effect.
Heartbeat Rate	16–1000 ms	Sets the rate at which heartbeat messages are sent from the 1355.
PDO Timeout	0–1000 ms	Sets the PDO timeout period. After the 1355 has sent a PDO MISO, it will declare a PDO Timeout Fault if the master controller has not sent a reply PDO-MOSI message within the programmed time. Either PDO1 MOSI or PDO2 MOSI will reset the timer. Setting this PDO Timeout = 0 will disable this fault check.

MISC MENU *(1355-X101 only)*

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Digital Input 1 Normally Closed	On / Off	On = Normally closed. Off = Normally open.
Digital Input 2 Normally Closed	On / Off	On = Normally closed. Off = Normally open.
Digital Input 3 Normally Closed	On / Off	On = Normally closed. Off = Normally open.
Digital Input 4 Normally Closed	On / Off	On = Normally closed. Off = Normally open.
Digital Input 5 Normally Closed	On / Off	On = Normally closed. Off = Normally open.
Digital Input 6 Normally Closed	On / Off	On = Normally closed. Off = Normally open.

Monitor Menus

Through its monitor menus, the Curtis programmer provides access to real-time data during vehicle operation. This information is helpful during diagnostics and troubleshooting, and also while adjusting programmable parameters.

The monitored variables are arranged in menus, as shown in Table 3.

Table 3 Monitor Menus: 1311/1313/1314 Programmer

CURRENT .... p. 18
- M1 Current
- M2 Current
- M3 Current
- M4 Current
- M5 Current
- Actuator 1 Current [a]
- Actuator 2 Current [a]
- Actuator 3 Current [a]

VOLTAGE .... p. 18
- KSI Voltage
- Battery Voltage

DUTY CYCLE .... p. 19
- M1 Duty Cycle
- M2 Duty Cycle
- M3 Duty Cycle
- M4 Duty Cycle
- M5 Duty Cycle
- Actuator 1 Duty Cycle [a]
- Actuator 2 Duty Cycle [a]
- Actuator 3 Duty Cycle [a]

CONTROLLER .... p. 20
- Internal Temperature
- Contactor State
- Interlock [b]
- Digital Input 1 [b]
- Digital Input 2 [b]
- Digital Input 3 [b]
- Digital Input 4 [b]
- Digital Input 5 [b]
- Digital Input 6 [b]
- M1 Hourmeter
- M2 Hourmeter
- M3 Hourmeter
- M4 Hourmeter
- M5 Hourmeter
- Actuator 1 Hourmeter [a]
- Actuator 2 Hourmeter [a]
- Actuator 3 Hourmeter [a]
- CAN NMT State

[a] 1355-X001 only
[b] 1355-X101 only

CURRENT MONITOR MENU		
PARAMETER	DISPLAY RANGE	DESCRIPTION
M1 Current	-150.0 – 150.0 A	M1 motor current.
M2 Current	-150.0 – 150.0 A	M2 motor current.
M3 Current	-150.0 – 150.0 A	M3 motor current.
M4 Current	-150.0 – 150.0 A	M4 motor current.
M5 Current	-150.0 – 150.0 A	M5 motor current.
Actuator1 Current *(1355-X001 only)*	0.0 – 15.0 A	Actuator1 motor current.
Actuator2 Current *(1355-X001 only)*	0.0 – 15.0 A	Actuator2 motor current.
Actuator3 Current *(1355-X001 only)*	0.0 – 15.0 A	Actuator3 motor current.

VOLTAGE MONITOR MENU		
PARAMETER	DISPLAY RANGE	DESCRIPTION
KSI Voltage	0.0 – 80.0 V	Voltage at KSI input, pin 9.
Battery Voltage	0.0 – 80.0 V	Voltage at the B+ busbar.

DUTY CYCLE MONITOR MENU		
PARAMETER	DISPLAY RANGE	DESCRIPTION
M1 Duty Cycle	0–100 %	M1 output duty cycle.
M2 Duty Cycle	0–100 %	M2 output duty cycle.
M3 Duty Cycle	0–100 %	M3 output duty cycle.
M4 Duty Cycle	0–100 %	M4 output duty cycle.
M5 Duty Cycle	0–100 %	M5 output duty cycle.
Actuator1 Duty Cycle *(1355-X001 only)*	-100–100 %	Actuator1 output duty cycle.
Actuator2 Duty Cycle *(1355-X001 only)*	-100–100 %	Actuator2 output duty cycle.
Actuator3 Duty Cycle *(1355-X001 only)*	-100–100 %	Actuator3 output duty cycle.

CONTROLLER MONITOR MENU

PARAMETER	DISPLAY RANGE	DESCRIPTION
Internal Temperature	-40 – 125°C	The internal temperature of the controller.
Contactor State	On / Off	Displays the state of the main contactor. On = main contactor closed. Off = main contactor open.
Interlock *(1355-X101 only)*	On / Off	Displays the state of the interlock.
Digital Input 1 *(1355-X101 only)*	On / Off	State of Digital Input 1.
. . .		
Digital Input 6 *(1355-X101 only)*	On / Off	State of Digital Input 6.
M1 Hourmeter	0 – 65535 hr	Each hourmeter accumulates "On" time while its corresponding motor is running.
M2 Hourmeter	0 – 65535 hr	
M3 Hourmeter	0 – 65535 hr	
M4 Hourmeter	0 – 65535 hr	
M5 Hourmeter	0 – 65535 hr	
Actuator1 Hourmeter *(1355-X001 only)*	0 – 65535 hr	
Actuator2 Hourmeter *(1355-X001 only)*	0 – 65535 hr	
Actuator3 Hourmeter *(1355-X001 only)*	0 – 65535 hr	
CAN NMT State	0 – 127	Displays the NMT state of the 1355. 0 = Initialization. 4 = Stopped. 5 = Operational. 127 = Pre-operational.

4

CANopen COMMUNICATIONS

The 1355 follows the industry trend (which Curtis proposed and supports) toward CANopen communications. The 1355 runs the minimum state machine, which contains the standard mandatory objects and follows the recommended SDO addressing scheme. The CANopen protocol application layer is fully compatible with Curtis AC motor controllers and system controllers, such as the 1310.

The 1355 processes two incoming PDOs (MOSI) and responds with two outgoing PDOs (MISO). These PDOs use a dynamic mapping method. All programmable parameters and monitor parameters are accessible by standard SDO transfer.

The time between incoming PDOs is monitored and if excessive, a fault will be reported. This allows the 1355 to know whether the system is under master control. The 1355 also produces a cyclic Heartbeat message, which is the CiA-preferred method for slave error control.

Emergency messages are sent sporadically whenever an error status flag within the 1355 changes state. A minimum time between emergency messages prevents the bus from being flooded.

BAUD RATES

The 1355 runs at one of three selectable baud rates: 125 kbps, 250 kbps, or 500 kbps. The baud rate can be changed by a Curtis programmer or by an SDO. Changes in the baud rate require an NMT reset or key cycle.

NODE ADDRESSES

The node address is used to route messages to the 1355 and to denote messages from the 1355. The node address is part of the COB ID and therefore also plays a part in message priority and bus arbitration.

The 1355 can be assigned node address 1 through 127; node address 0 is reserved and unavailable.

Changes to the node address require an NMT reset or key cycle.

HEARTBEAT

The heartbeat message is a very low priority message, periodically sent by each slave device on the bus. The heartbeat message has a single byte of data and requires no response. Once the 1355 completes its initialization, the first heartbeat will be issued and will continue until communication is stopped.

The heartbeat message has only one data byte. The top bit is reserved and should be set to zero. The bottom 7 bits hold the current NMT device state.

EMERGENCY MESSAGES

Emergency messages are high priority messages that announce the setting or clearing of a fault in a slave device. These messages are originated by the slave, which sends 8 bytes of data.

Internal to the device, each fault is mapped to one of the device's supported "Error Categories" from an extensive list of possible Error Categories defined by CANopen. The fault reporting scheme ensures that one Emergency message is sent in a CAN bus processing cycle during which one or more faults within a given Error Category have been set or cleared. If a single fault has occurred since the last processing cycle, then only one Emergency message is sent until such time as either a new fault is detected or the previously reported fault has cleared. If multiple faults are detected in a given cycle, the first fault is sent immediately, and the remaining faults are queued. Queued faults are sent on successive processing cycles until the queue is empty. The same scheme applies to the concurrent clearing of faults and their corresponding Emergency messages.

The Emergency message will have device-specific fault bytes in addition to the CANopen mandatory Error Register and Error Category. Note: Bit 0 of the Error Register object must always be set to 1 in any error situation.

Data Bytes 1 and 2 – Error Category

These data bytes, which are not explicitly defined by CANopen, are used to provide narrower categorization up to and including individual faults when deemed appropriate. The error category value implies the values that will appear in bytes 4 through 8 of the error message (the "Manufacture Specific Error Field"). These additional bytes are used to provide supporting information about the particular fault or faults being reported in an Error Category by a given Emergency message. The following error categories are defined:

0x0000	Fault Reset or No Fault
0x1000	Generic Fault
0x1001	Generic Fault

Please refer to the product specific CANopen implementation manual for lists of errors occurring under each of these categories

Data Byte 3 – Error Register

CANopen requires that the object ID of the error_register be included in each Emergency message. Currently, only bit 0 of the Error Register is defined. This bit is set when any of the faults are set.

Data Bytes 4 through 8 – Manufacture Specific Error Field

The values that appear in these last 5 bytes depend on the Error Category that is being reported. The last 5 bytes are defined as follows.

Error Category	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x1000	Diagnostic1	Diagnostic2	Diagnostic3	Diagnostic4	Diagnostic5
0x1001	Diagnostic6	Diagnostic7	Diagnostic8	Diagnostic9	Diagnostic10

PDOs

The PDO (**P**rocess **D**ata **O**bject) communication packets conserve bus bandwidth by bundling the values of a group of objects into a single message. The 1355 uses four PDOs, two from the system master and two responsive PDOs sent from the 1355 itself. The content of these PDOs can be dynamic mapped as Curtis AC motor controllers. PDO messages have a medium priority and always carry 8 bytes of data. The Curtis CANopen implementation requires that the incoming (Master Out Slave In) PDOs be immediately responded to by an outgoing (Master In Slave Out) PDO. The 1355 will respond to the PDO-MOSI with its PDO-MISO within 16 ms.

The 1355 requires that the PDO-MOSI be cyclic from the master. The cycle time must be less than the programmed PDO Timeout. If the PDO-MOSI is not received within the programmed time, the 1355 will flag a fault and enter the Pre-Operational State. If the PDO Timeout parameter is set to 0, the timeout fault is disabled and the 1355 will respond to any PDO incoming at any rate without faulting.

These charts show the PDOs exchanged by the 1355 with default mapping.

PDO1-MOSI *(received from the system master)*

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Actuator 1 PWM Low	Actuator 1 PWM High	Actuator 2 PWM Low	Actuator 2 PWM High	Actuator 3 PWM Low	Actuator 3 PWM High	M1 PWM Demand Low	M1 PWM Demand High

PDO1-MISO *(sent in response to the system master)*

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Actuator 1 Current Low	Actuator 1 Current High	Actuator 2 Current Low	Actuator 2 Current High	Actuator 3 Current Low	Actuator 3 Current High/switch inputs status	M1 PWM Current Low	M1 PWM Current High

PDO2-MOSI *(received from the system master)*

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
M2 PWM Demand Low	M2 PWM Demand High	M3 PWM Demand Low	M3 PWM Demand High	M4 PWM Demand Low	M4 PWM Demand High	M5 PWM Demand Low	M5 PWM Demand High

PDO2-MISO *(sent in response to the system master)*

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
M2 Current Low	M2 Current High	M3 Current Low	M3 Current High	M4 Current Low	M4 Current High	M5 Current Low	M5 Current High

Note: Actuator objects are only for the 1355-X001.
The switch inputs status object is only for the 1355-X101.

SDOs

SDOs (**S**ervice **D**ata **O**bjects) are low priority packets that are designed for sporadic and occasional use during normal runtime operation. There are two types of SDOs: expedited and block transfer. The 1355 does not support large file uploads or downloads (using the block transfer), so all the SDOs used by the 1355 are expedited SDOs.

The SDOs in the 1355 are used to set up and parameterize the module. They are also used to retrieve basic module information (such as version or manufacture date) and monitor a few key internal variables (mostly for system debug purposes). There are two types of SDO objects: Communication Profile Objects and Parameter Profile Objects.

COMMUNICATION PROFILE OBJECTS

The communiction profile objects are shown below in Table 4.

Table 4 Communication Profile Object Dictionary

NAME	ACCESS	INDEX	SUB-INDEX	VALUE *BYTES*	DESCRIPTION
Device Type	RO	0x1000	0x00	0x00000000 *4 bytes*	Predefined type of CAN module.
Error Register	RO	0x1001	0x00	0x00 or 0x01 *1 byte*	= 0x01 if there is an error. = 0x00 if there are no errors.
Node ID	RW	0x100B	0x00	0x01–0x7F *1 byte*	Node ID of this 1355 module.
Emergency COB ID	RO	0x1014	0x00	0x00000080– 0x000000FF *4 bytes*	11-bit identifier of the emergency message. Only the lowest 11 bits are valid. All other bits must be 0.
Heartbeat Rate	RW	0x1017	0x00	16 ms–1 s, in 4 ms steps *2 bytes*	Sets the cyclic repetition rate of the heartbeat message.
Identity Object	RO	0x1018	0x00	0x06 *1 byte*	Length of this structure = 6 subindexes.
			0x01	0x00434900 *4 bytes*	Curtis ID as defined by CiA.
			0x02	0x054B0FA1 *4 bytes*	Product code: 2 upper bytes = 1355. 2 lower bytes = model, X001 or X101.
			0x03	0x01020304 *4 bytes*	Master version in upper 2 bytes and Slave version in lower 2 bytes. The bytes are split upper byte for HW and lower byte for SW. Example: Master HW version 1 with SW version 2, and Slave HW version 3 with SW version 4 = 01020304. For 1355-X101, the lower 2 bytes are 0.
			0x04	0–999999 *4 bytes*	Serial number, up to 999,999.
			0x05	1–99366 *4 bytes*	Date code up to 99, Dec 31.
			0x06	A–Z *0x41–0x5A*	ASCII code of manufacturer's location.

PARAMETER PROFILE OBJECTS

The parameter profile objects are shown in Table 5.

Table 5 Parameter Profile Object Dictionary

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
PDO1 MOSI Parameters	RO	0x1400	0x00	1	No	Number of PDO1 MOSI parameters.
			0x01	n/a		The first parameters of PDO1 MOSI.
PDO2 MOSI Parameters	RO	0x1401	0x00	1	No	Number of PDO2 MOSI parameters.
			0x01	n/a		The first parameters of PDO2 MOSI.
PDO1 MOSI Mapping	RW	0x1600	0x00	n/a	No	Number of mapped application objects in PDO1 MOSI.
PDO1 MOSI Mapping 1			0x01			PDO1 MOSI mapping for the 1st application object to be mapped.
PDO1 MOSI Mapping 2			0x02			PDO1 MOSI mapping for the 2nd application object to be mapped.
. . .			. . .			PDO1 MOSI mapping for 3rd–7th objects.
PDO1 MOSI Mapping 8			0x08			PDO1 MOSI mapping for the 8th application object to be mapped.
PDO2 MOSI Mapping	RW	0x1601	0x00	n/a	No	Number of mapped application objects in PDO2 MOSI.
PDO2 MOSI Mapping 1			0x01			PDO2 MOSI mapping for the 1st application object to be mapped.
PDO2 MOSI Mapping 2			0x02			PDO2 MOSI mapping for the 2nd application object to be mapped.
. . .			. . .			PDO2 MOSI mapping for 3rd–7th objects.
PDO2 MOSI Mapping 8			0x08			PDO2 MOSI mapping for the 8th application object to be mapped.
PDO1 MISO Parameters	RO	0x1800	0x00	1	No	Number of PDO1 MISO parameters.
			0x01	n/a		The first parameters of PDO1 MISO.
PDO2 MISO Parameters	RO	0x1801	0x00	1	No	Number of PDO2 MISO parameters.
			0x01	n/a		The first parameters of PDO2 MISO.
PDO1 MISO Mapping	RW	0x1A00	0x00	n/a	No	Number of mapped application objects in PDO1 MISO.
PDO1 MISO Mapping 1			0x01	n/a	No	PDO1 MISO mapping for the 1st application object to be mapped.
PDO1 MISO Mapping 2			0x02	n/a	No	PDO1 MISO mapping for the 2nd application object to be mapped.
. . .			. . .	n/a	No	PDO1 MISO mapping for 3rd–7th objects.
PDO1 MISO Mapping 8			0x08	n/a	No	PDO1 MISO mapping for the 8th application object to be mapped.

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
PDO2 MISO Mapping	RW	0x1A01	0x00	n/a	No	Number of mapped application objects in PDO2 MISO.
PDO2 MISO Mapping 1			0x01			PDO2 MISO mapping for the 1st application object to be mapped.
PDO2 MISO Mapping 2			0x02			PDO2 MISO mapping for the 2nd application object to be mapped.
. . .			. . .			PDO2 MISO mapping for 3rd–7th objects.
PDO2 MISO Mapping 8			0x08			PDO2 MISO mapping for the 8th application object to be mapped.
Nominal Voltage	RW	0x3048	0x00	1536–2304, 2304–3072	No	24–36V for 1355-4X01, 36–48V for 1355-5X01.
M1 Current Limit	RW	0x3101	0x00	100–1000, or 100–700	No	Defines the maximum current of M1: 10–100A for 1355-4X01 and 10–70A for 1355-5X01.
M2 Current Limit	RW	0x3102	0x00	100–1000, or 100–700	No	Defines the maximum current of M2: ranges are as shown for M1.
M3 Current Limit	RW	0x3103	0x00	100–1000, or 100–700	No	Defines the maximum current of M3: ranges are as shown for M1.
M4 Current Limit	RW	0x3104	0x00	100–1000, or 100–700	No	Defines the maximum current of M4: ranges are as shown for M1.
M5 Current Limit	RW	0x3105	0x00	100–1000, or 100–700	No	Defines the maximum current of M5: ranges are as shown for M1.
Motor Control	RW	0x3106	0x00	0–255	Yes	bit0 controls M1 1=Run 0=Stop. bit1 controls M2 1=Run 0=Stop. bit2 controls M3 1=Run 0=Stop. bit3 controls M4 1=Run 0=Stop. bit4 controls M5 1=Run 0=Stop. bit5 controls H Bridge direction: 1=Fwd 0=Rev. Note: in H-Bridge mode, the 1355 uses the parameters of M1; M2's parameters are ignored.
Motor Mode	RW	0x3107	0x00	0–255	Yes	bit0 M1 PWM mode 1=Active 0=Inactive. bit1 M2 PWM mode 1=Active 0=Inactive. bit2 M3 PWM mode 1=Active 0=Inactive. bit3 M4 PWM mode 1=Active 0=Inactive. bit4 M5 PWM mode 1=Active 0=Inactive.
M1 Overload Time	RW	0x3108	0x00	1000–20000	No	Defines the max overload time: 1000–20000 ms. The output is shut down once the timer expires.
M2 Overload Time	RW	0x3109	0x00	1000–20000	No	
M3 Overload Time	RW	0x310A	0x00	1000–20000	No	
M4 Overload Time	RW	0x310B	0x00	1000–20000	No	
M5 Overload Time	RW	0x310C	0x00	1000–20000	No	

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
M1 Accel	RW	0x310D	0x00	1–20	No	0.1–2.0 s
M2 Accel	RW	0x310E	0x00	1–20	No	0.1–2.0 s
M3 Accel	RW	0x310F	0x00	1–20	No	0.1–2.0 s
M4 Accel	RW	0x3113	0x00	1–20	No	0.1–2.0 s
M5 Accel	RW	0x3114	0x00	1–20	No	0.1–2.0 s
M1 PWM Demand	RW	0x3118	0x00	0–32767	Yes	0–100 %
M2 PWM Demand	RW	0x3119	0x00	0–32767	Yes	0–100 %
M3 PWM Demand	RW	0x311A	0x00	0–32767	Yes	0–100 %
M4 PWM Demand	RW	0x311B	0x00	0–32767	Yes	0–100 %
M5 PWM Demand	RW	0x311C	0x00	0–32767	Yes	0–100 %
M1 M2 H Bridge Mode	RW	0x311D	0x00	0–1	No	0=H Bridge mode inactive; 1=H Bridge mode active.
M4 M5 Parallel Mode	RW	0x311E	0x00	0–1	No	0=Parallel mode inactive; 1=Parallel mode active. Note: In Parallel mode, the 1355 uses M4's parameters. M5's parameters are ignored except for the current limit. The current limit range in Parallel mode is 20–200A, which is the total current limit of M4 and M5.
Motor Enable	RW	0x311F	0x00	0–255	No	bit0 M1 Enable. bit1 M2 Enable. bit2 M3 Enable. bit3 M4 Enable. bit4 M5 Enable. bit5 Actuator1 Enable. [a] bit6 Actuator2 Enable. [a] bit7 Actuator3 Enable. [a] When the output is disabled, the 1355 will not check the relative faults except for some severe faults such as motor short and current sensor fault.
M1 Duty Cycle	RO	0x3120	0x00	0–32767	Yes	0–100%
M2 Duty Cycle	RO	0x3121	0x00	0–32767	Yes	0–100%
M3 Duty Cycle	RO	0x3122	0x00	0–32767	Yes	0–100%
M4 Duty Cycle	RO	0x3123	0x00	0–32767	Yes	0–100%
M5 Duty Cycle	RO	0x3124	0x00	0–32767	Yes	0–100%
M1 Armature Current	RO	0x3126	0x00	-1500–1500	Yes	-150.0–150.0 A
M2 Armature Current	RO	0x3127	0x00	-1500–1500	Yes	-150.0–150.0 A
M3 Armature Current	RO	0x3128	0x00	-1500–1500	Yes	-150.0–150.0 A
M4 Armature Current	RO	0x3129	0x00	-1500–1500	Yes	-150.0–150.0 A
M5 Armature Current	RO	0x312A	0x00	-1500–1500	Yes	-150.0–150.0 A

[a] 1355-X001 only

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Baud Rate	RW	0x3142	0x00	0–2	No	0 = 125 kbps. 1 = 250 kbps. 2 = 500 kbps. The default setting is 1 (250 kbps).
PDO Timeout	RW	0x3149	0x00	0–1000	No	Time interval within which the PDO-MOSI must be received or a fault will be flagged. The default setting is 100 ms.
Diagnostic1	RO	0x3256	0x00	0–255	Yes	bit0 Precharge Fault. bit1 Main Contactor Overload. bit2 Main Weld Fault. bit3 Main DNC Fault. bit4 Overvoltage Warning. bit5 Undervoltage Warning. bit6 Overvoltage Cutoff. bit7 Undervoltage Cutoff.
Diagnostic2	RO	0x3257	0x00	0–255	Yes	bit0 M1 Open. bit1 M2 Open. bit2 M3 Open. bit3 M4 Open. bit4 M5 Open. bit5 Actuator1 Open.[a] bit6 Actuator2 Open.[a] bit7 Actuator3 Open.[a]
Diagnostic3	RO	0x3258	0x00	0–255	Yes	bit0 M1 Overload Warning. bit1 M2 Overload Warning. bit2 M3 Overload Warning. bit3 M4 Overload Warning. bit4 M5 Overload Warning. bit5 Actuator1 Overload Warning.[a] bit6 Actuator2 Overload Warning.[a] bit7 Actuator3 Overload Warning.[a]
Diagnostic4	RO	0x3259	0x00	0–255	Yes	bit0 M1 Over Current. bit1 M2 Over Current. bit2 M3 Over Current. bit3 M4 Over Current. bit4 M5 Over Current. bit5 Actuator1 Over Current.[a] bit6 Actuator2 Over Current.[a] bit7 Actuator3 Over Current.[a]
Diagnostic5	RO	0x325A	0x00	0–255	Yes	bit0 M1 Motor Short. bit1 M2 Motor Short. bit2 M3 Motor Short. bit3 M4 Motor Short. bit4 M5 Motor Short. bit5 Actuator1 Motor Short.[a] bit6 Actuator2 Motor Short.[a] bit7 Actuator3 Motor Short.[a]

[a] 1355-X001 only

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Diagnostic6	RO	0x325B	0x00	0–255	Yes	bit0 M1 Current Sensor Fault. bit1 M2 Current Sensor Fault. bit2 M3 Current Sensor Fault. bit3 M4 Current Sensor Fault. bit4 M5 Current Sensor Fault. bit5 Over Temperature Cutoff. bit6 Under Temperature Cutoff. bit7 [reserved].
Diagnostic7	RO	0x325C	0x00	0–255	Yes	bit0 M1 Overload Trip. bit1 M2 Overload Trip. bit2 M3 Overload Trip. bit3 M4 Overload Trip. bit4 M5 Overload Trip. bit5 Actuator1 Stall Fault.[a] bit6 Actuator2 Stall Fault.[a] bit7 Actuator3 Stall Fault.[a]
Diagnostic8	RO	0x325D	0x00	0–255	Yes	bit0 EEPROM Fault. bit1 PDO Timeout Fault. bit2 CAN Bus Fault. bit3 Actuator Timeout.[a] bit4 Sequence Fault.[b] bit5 Over Temperature Cutback. bit6 Under Temperature Cutback. bit7 Main Missing Fault.
Fault History1	RO	0x325E	0x00	0–255	Yes	bit0 Precharge Fault. bit1 Main Contactor Overload. bit2 Main Weld Fault. bit3 Main DNC Fault. bit4 [reserved]. bit5 [reserved]. bit6 Overvoltage Cutoff. bit7 Undervoltage Cutoff.
Fault History2	RO	0x325F	0x00	0–255	Yes	See Diagostic2.
Fault History3	RO	0x3260	0x00	0–255	Yes	[reserved]
Fault History4	RO	0x3261	0x00	0–255	Yes	See Diagostic4.
Fault History5	RO	0x3262	0x00	0–255	Yes	See Diagostic5.
Fault History6	RO	0x3263	0x00	0–255	Yes	See Diagostic6.
Fault History7	RO	0x3264	0x00	0–255	Yes	See Diagostic7.
Fault History8	RO	0x3265	0x00	0–255	Yes	See Diagostic8.
M1 Hourmeter	RO	0x3266	0x00	0–65535	Yes	0–65535 hr
M2 Hourmeter	RO	0x3267	0x00	0–65535	Yes	0–65535 hr
M3 Hourmeter	RO	0x3268	0x00	0–65535	Yes	0–65535 hr
M4 Hourmeter	RO	0x3269	0x00	0–65535	Yes	0–65535 hr
M5 Hourmeter	RO	0x326A	0x00	0–65535	Yes	0–65535 hr

[a] 1355-X001 only
[b] 1355-X101 only

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Internal Temperature	RO	0x326E	0x00	-40–125	Yes	-40–125 °C.
M1 Regen Current Limit	RW	0x326F	0x00	100–1000 100-700	Yes	1355-4X01: 10.0–100.0 A 1355-5X01: 10.0–70.0 A
M2 Regen Current Limit	RW	0x3270	0x00	100–1000 100-700	Yes	1355-4X01: 10.0–100.0 A 1355-5X01: 10.0–70.0 A
M3 Regen Current Limit	RW	0x3271	0x00	100–1000 100-700	Yes	1355-4X01: 10.0–100.0 A 1355-5X01: 10.0–70.0 A
M4 Regen Current Limit	RW	0x3272	0x00	100–1000 100-700	Yes	1355-4X01: 10.0–100.0 A 1355-5X01: 10.0–70.0 A
M5 Regen Current Limit	RW	0x3273	0x00	100–1000 100-700	Yes	1355-4X01: 10.0–100.0 A 1355-5X01: 10.0–70.0 A
M1 Open Current	RW	0x3275	0x00	0–100	Yes	0.0–10.0 A
M2 Open Current	RW	0x3276	0x00	0–100	Yes	0.0–10.0 A
M3 Open Current	RW	0x3277	0x00	0–100	Yes	0.0–10.0 A
M4 Open Current	RW	0x3278	0x00	0–100	Yes	0.0–10.0 A
M5 Open Current	RW	0x3279	0x00	0–100	Yes	0.0–10.0 A
Overload Trip Reset	RW	0x327A	0x00	0–255	Yes	bit0 1 Clear M1 Overload Trip Fault. bit1 1 Clear M2 Overload Trip Fault. bit2 1 Clear M3 Overload Trip Fault. bit3 1 Clear M4 Overload Trip Fault. bit4 1 Clear M5 Overload Trip Fault. bit5–7 [reserved].
Diagnostic9	RO	0x3280	0x00	0–255	Yes	bit0 M1 HW Fault. bit1 M2 HW Fault. bit2 M3 HW Fault. bit3 M4 HW Fault. bit4 M5 HW Fault. bit5 Parameter Change Fault. bit6 Actuator1 Current Sensor Fault.[a] bit7 Actuator2 Current Sensor Fault.[a]
Diagnostic10	RO	0x3281	0x00	0–255	Yes	bit0 Actuator3 Current Sensor Fault.[a] bit1 Thermal Sensor Fault. bit2 Main Coil Short Fault. bit3–7 [reserved].
Fault History9	RO	0x3282	0x00	0–255	Yes	See Diagostic9.
Fault History10	RO	0x3283	0x00	0–255	Yes	See Diagostic10.
M1 Decel	RW	0x3284	0x00	1–20	No	0.1–2.0 s
M2 Decel	RW	0x3285	0x00	1–20	No	0.1–2.0 s
M3 Decel	RW	0x3286	0x00	1–20	No	0.1–2.0 s
M4 Decel	RW	0x3287	0x00	1–20	No	0.1–2.0 s
M5 Decel	RW	0x3288	0x00	1–20	No	0.1–2.0 s

[a] 1355-X001 only

Table 5 Parameter Profile Object Dictionary, cont'd

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Overvoltage Warning Range	RW	0x3604	0x00	0–4096	No	2.0–14.0 V. Sets voltage allowed above nominal voltage. When the capacitor bank voltage exceeds (Nominal Voltage + Overvoltage Warning Range), an over-voltage warning is sent on the CAN bus and the programmer.
Undervoltage Warning Range	RW	0x3605	0x00	0–4096	No	2.0–14.0 V. Sets voltage allowed below nominal voltage. When the capacitor bank voltage drops below (Nominal Voltage - Overvoltage Warning Range), an under-voltage warning is sent on the CAN bus and the programmer.
Battery Voltage	RO	0x3800	0x00	0–800	No	0.0–80.0 V

The objects in Table 5a apply only to the 1355-X001.

Note: There are some actuator objects in the main table above (Table 5) that also apply only to the 1355-X001.

Table 5a Parameter Profile Object Dictionary: 1355-X001 only

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Actuator1 PWM Demand	RW	0x312C	0x00	-32767– 32767	Yes	-100–100 %
Actuator2 PWM Demand	RW	0x312D	0x00	-32767– 32767	Yes	-100–100 %
Actuator3 PWM Demand	RW	0x312E	0x00	-32767– 32767	Yes	-100–100 %
Actuator1 Accel	RW	0x312F	0x00	1–20	No	0.1–2.0 s
Actuator2 Accel	RW	0x3130	0x00	1–20	No	0.1–2.0 s
Actuator3 Accel	RW	0x3131	0x00	1–20	No	0.1–2.0 s
Actuator1 Decel	RW	0x3132	0x00	1–20	No	0.1–2.0 s
Actuator2 Decel	RW	0x3133	0x00	1–20	No	0.1–2.0 s
Actuator3 Decel	RW	0x3134	0x00	1–20	No	0.1–2.0 s
Actuator1 Stall Current Limit	RW	0x3135	0x00	20–100	No	2.0–10.0 A
Actuator2 Stall Current Limit	RW	0x3136	0x00	20–100	No	2.0–10.0 A
Actuator3 Stall Current Limit	RW	0x3137	0x00	20–100	No	2.0–10.0 A
Actuator1 Stall Debounce	RW	0x3138	0x00	0–50	No	0.0–5.0 s
Actuator2 Stall Debounce	RW	0x3139	0x00	0–50	No	0.0–5.0 s
Actuator3 Stall Debounce	RW	0x313A	0x00	0–50	No	0.0–5.0 s
Actuator1 Duty Cycle	RO	0x3250	0x00	-32767– 32767	Yes	-100–100 %
Actuator2 Duty Cycle	RO	0x3251	0x00	-32767– 32767	Yes	-100–100 %
Actuator3 Duty Cycle	RO	0x3252	0x00	-32767– 32767	Yes	-100–100 %
Actuator1 Armature Current	RO	0x3253	0x00	0–150	Yes	0.0–15.0 A
Actuator2 Armature Current	RO	0x3254	0x00	0–150	Yes	0.0–15.0 A
Actuator3 Armature Current	RO	0x3255	0x00	0–150	Yes	0.0–15.0 A
Actuator1 Hourmeter	RO	0x326B	0x00	0–65535	Yes	0–65535 hr
Actuator2 Hourmeter	RO	0x326C	0x00	0–65535	Yes	0–65535 hr
Actuator3 Hourmeter	RO	0x326D	0x00	0–65535	Yes	0–65535 hr

The objects in Table 5b apply only to the 1355-X101.

Note: Two items in the main table above (Table 5) also apply only to the 1355-X101: Diagnostics8 bit4, Sequence Fault, and the corresponding bit in Fault History8.

Table 5b Parameter Profile Object Dictionary: 1355-X101 only

NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Operation Mode	RW	0x3801	0x00	0–1	No	0: Independent mode. 1: CAN Slave mode.
M1 Controlled By	RW	0x3802	0x00	0–6	No	Defines which digital input will turn the output of this motor on/off. 0: not controlled by digital input. 1–6: controlled by digital input 1–6.
M2 Controlled By	RW	0x3803	0x00	0–6	No	See above.
M3 Controlled By	RW	0x3804	0x00	0–6	No	See above.
M4 Controlled By	RW	0x3805	0x00	0–6	No	See above.
M5 Controlled By	RW	0x3806	0x00	0–6	No	See above.
M1 Inhibited By	RW	0x3807	0x00	0–6	No	Defines which digital input will inhibit the output of this motor. 0: not controlled by digital input. 1–6: controlled by digital input 1–6.
M2 Inhibited By	RW	0x3808	0x00	0–6	No	See above.
M3 Inhibited By	RW	0x3809	0x00	0–6	No	See above.
M4 Inhibited By	RW	0x380A	0x00	0–6	No	See above.
M5 Inhibited By	RW	0x380B	0x00	0–6	No	See above.
M1 Output Off Delay	RW	0x380C	0x00	0–300	No	0.0–30.0 s This motor's PWM will be shut off after the set delay time expires following a stop command.
M2 Output Off Delay	RW	0x380D	0x00	0–300	No	See above.
M3 Output Off Delay	RW	0x380E	0x00	0–300	No	See above.
M4 Output Off Delay	RW	0x380F	0x00	0–300	No	See above.
M5 Output Off Delay	RW	0x3810	0x00	0–300	No	See above.
Digital Inputs Normally Closed	RW	0x3811	0x00	0–0x3F	No	Setting the relevant bit to 1 inverts the signal. bit0 Digital input 1. bit1 Digital input 2. bit2 Digital input 3. bit3 Digital input 4. bit4 Digital input 5. bit5 Digital input 6. bit6–7 [reserved]..
Startup Lockout Type	RW	0x3812	0x00	0–2	No	0: No startup lockout. 1: KSI-type startup lockout. 2: Interlock-type startup lockout.

Table 5b Parameter Profile Object Dictionary: 1355-X101 only, cont'd						
NAME	ACCESS	INDEX	SUB-INDEX	RANGE RAW	MAPPING	DESCRIPTION
Sequence Delay	RW	0x3813	0x00	0–50	No	0.0–5.0 s. PWM shutoff delay when the interlock switch is turned off.
M1 M2 Bridge Direction Input	RW	0x3814	0x00	1–6	No	Selects which digital input (1–6) will provide the H Bridge direction command. Digital input On = Forward. Digital input Off = Reverse. Note: When the 1355 is operating in Can Slave mode, this parameter is ignored.
Interlock Type	RW	0x3815	0x00	0–1	No	0: Interlock turns on with digital input 6. 1: Interlock turns on with KSI.
Switch Input States	RO	0x3900	0x00	0–0x3F	Yes	States of the digital inputs. 1 = On. 0 = Off. bit0 Digital input 1. bit1 Digital input 2. bit2 Digital input 3. bit3 Digital input 4. bit4 Digital input 5. bit5 Digital input 6. bit6–7 [reserved].

5 DIAGNOSTICS AND TROUBLESHOOTING

When an error occurs in the 1355, a fault message can be monitored through the Curtis programmer. Meanwhile, an emergency message will be produced on the CAN bus according to the CANopen standard. This message will be sent once. When the fault clears, a No Fault emergency message will be transmitted.

The pair of LEDs built into the controller (one red, one yellow) produce flash codes displaying all the currently set faults in a repeating cycle. The red LED indicates the digit place and the yellow LED indicates the value. For example, a code 23 would be displayed as one red flash, followed by two yellow flashes, followed by two red flashes and finished with three yellow flashes.

RED	YELLOW	RED	YELLOW
*	* *	* *	* * *
(first digit)	(2)	(second digit)	(3)

The fault codes are listed in the troubleshooting chart (Table 6).

During normal operation, the yellow LED flashes continuously.

On power-up, the integrity of the code stored in memory is automatically tested. If the software is found to be corrupted, the red Status LED will flash rapidly.

Table 6 TROUBLESHOOTING CHART

CODE	FAULT	DESCRIPTION	EFFECT	RECOVERY
Fast Red LED	Corrupt Code	1355 in corrupted state.	1355 in Fault state.	Requires repair or new software download.
11	Precharge Fault	1355 failed to charge the capacitor bank to the KSI voltage.	Main contactor cannot be closed and disable all PWM outputs.	Clear condition & cycle KSI.
12	Main Contactor Overload	Main contactor current is higher than the Main Contactor Current Limit.	Emergency message sent on CAN bus and all output currents reduced until main contactor current is below limit.	Clear condition.
13	Main Weld Fault	Main contactor is welded.	All PWM outputs disabled and main contactor opened.	Clear condition & cycle KSI.
14	Main DNC Fault	Main contactor did not close.	All PWM outputs disabled and main contactor opened.	Clear condition & cycle KSI.
15	Overvoltage Warning	Capacitor bank voltage exceeded the overvoltage warning limit.	Warning message sent.	Clear condition.
16	Undervoltage Warning	Capacitor bank voltage dropped below the undervoltage warning limit.	Warning message sent.	Clear condition.
17	Overvoltage Cutoff	Capacitor bank voltage exceeded the overvoltage cutoff limit.	All PWM outputs disabled and main contactor opened.	Clear condition.
18	Undervoltage Cutoff	Capacitor bank voltage dropped below the undervoltage cutoff limit.	All PWM outputs disabled.	Clear condition.
21	M1 Open	M1 Motor is open.	None.	Clear condition & cycle KSI.
22, 23, 24, 25	These faults are like #21, for the remaining four motors: M2, M3, M4, M5.			
26[a]	Actuator 1 Open	Actuator 1 motor is open.	None.	Clear condition & cycle KSI.
27[a], 28[a]	These faults are like #26, for the remaining two actuators: Actuator 2 and Actuator 3.			
31	M1 Overload Warning	With M1 output at 100% PWM, the load current exceeded the M1 current limit.	Emergency message sent on CAN bus.	Clear condition.
32, 33, 34, 35	These faults are like #31, for the remaining four motors: M2, M3, M4, M5.			
36[a]	Actuator 1 Overload	Actuator 1's energy integral is higher than the threshold.	Emergency message sent on CAN bus.	Clear condition.
37[a], 38[a]	These faults are like #36, for the remaining two actuators: Actuator 2 and Actuator 3.			
41	M1 Over Current	M1 current exceeded the max current of the hardware trip.	M1 PWM output disabled and main contactor opened.	Clear condition & cycle KSI.
42, 43, 44, 45	These faults are like #41, for the remaining four motors: M2, M3, M4, M5.			
46[a]	Actuator 1 Over Current	Actuator 1 current exceeded the max current of the hardware trip.	Actuator 1 PWM output disabled and main contactor opened.	Clear condition & cycle KSI.
47[a], 48[a]	These faults are like #46, for the remaining two actuators: Actuator 2 and Actuator 3.			

[a] 1355-X001 only

Table 6 TROUBLESHOOTING CHART, cont'd

CODE	FAULT	DESCRIPTION	EFFECT	RECOVERY
51	M1 Motor Short	M1 load is shorted.	M1 PWM output disabled and main contactor opened.	Clear condition & cycle KSI.
52, 53, 54, 55	These faults are like #51, for the remaining four motors: M2, M3, M4, M5.			
56[a]	Actuator 1 Motor Short	Actuator 1 load is shorted.	Actuator1 PWM output disabled and main contactor opened.	Clear condition & cycle KSI.
57[a], 58[a]	These faults are like #56, for the remaining two actuators: Actuator 2 and Actuator 3.			
61	M1 Current Sensor Fault	M1 current sensor has invalid reading.	M1 PWM output disabled.	Clear condition & cycle KSI.
62, 63, 64, 65	These faults are like #61, for the remaining four motors: M2, M3, M4, M5.			
66	Over Temperature Cutoff	Internal temperature exceeds cutoff temperature threshold.	All PWM outputs disabled.	Clear condition.
67	Under Temperature Cutoff	Internal temperature below -40°C.	All PWM outputs disabled.	Clear condition.
71	M1 Overload Trip	M1 overload timer expired.	M1 PWM output disabled.	Clear condition & cycle KSI, or receive CAN Clear message.
72, 73, 74, 75	These faults are like #71, for the remaining four motors: M2, M3, M4, M5.			
76[a]	Actuator 1 Stall Fault	Actuator 1 stall timer expired.	Actuator1 PWM output disabled and main contactor opened.	Operate in the opposite direction, or cycle KSI.
77[a], 78[a]	These faults are like #76, for the remaining two actuators: Actuator 2 and Actuator 3.			
81	EEPROM Fault	EEPROM checksum error.	All PWM outputs disabled.	Modify any programmable parameter with programmer.
82	PDO Timeout Fault	Time between PDO messages exceeded the PDO Timeout setting.	CANopen status in Pre-operation and all PWM outputs disabled.	Receive NMT message or cycle KSI.
83	CAN Bus Fault	Internal CAN bus error counter register exceeded 128.	Reset CAN bus.	Clear condition.
84[a]	Actuator Timeout	Master did not receive any message from the slave within timeout period.	All PWM outputs disabled.	Clear condition & cycle KSI.
85[b]	Sequence Fault	KSI, interlock, and startup requests applied in incorrect order.	All PWM outputs disabled.	Clear condition & cycle KSI.
86	Over Temperature Cutback	Internal temperature exceeds cutback temperature threshold.	Current limit reduced.	Clear condition.
87	Under Temp-erature Cutback	Internal temperature below -25°C.	Current limit reduced to 50%.	Clear condition.
88	Main Missing Fault	Main contactor coil not connected to main contactor driver.	All PWM outputs disabled.	Clear condition & cycle KSI.
91	M1 HW Fault	M1 output defective.	All PWM outputs disabled and main contactor opened.	Clear condition & cycle KSI.
92, 93, 94, 95	These faults are like #91, for the remaining four motors: M2, M3, M4, M5.			

[a] 1355-X001 only
[b] 1355-X101 only

Table 6 TROUBLESHOOTING CHART, cont'd

CODE	FAULT	DESCRIPTION	EFFECT	RECOVERY
96	Parameter Change Fault	Changing output mode (H Bridge Mode or Parallel Mode). *For 1355-X101 only:* • Inappropriate function setting of digital input (i.e., simultaneously set as Mx Inhibited By and Mx Controlled By), or • Interlock Type changed, or • Digital Input 6 used as both an interlock and inhibited or controlled input.	All PWM outputs disabled and main contactor opened.	Clear condition & cycle KSI.
97 [a]	Actuator 1 Current Sensor Fault	Actuator 1 current sensor has invalid reading.	Actuator 1 disabled.	Clear condition & cycle KSI.
98 [a], 101 [a]	These faults are like #97, for the remaining two actuators: Actuator 2 and Actuator 3.			
102	Temperature Sensor Fault	Temperature sensor has invalid reading.	All outputs disabled.	Clear condition & cycle KSI.
103	Main Coil Short Fault	Main contactor coil shorted.	All outputs disabled and main contactor opened.	Clear condition & cycle KSI.

[a] 1355-X001 only

APPENDIX A

VEHICLE DESIGN CONSIDERATIONS

ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) encompasses two areas: emissions and immunity. *Emissions* are radio frequency (RF) energy generated by a product. This energy has the potential to interfere with communications systems such as radio, television, cellular phones, dispatching, aircraft, etc. *Immunity* is the ability of a product to operate normally in the presence of RF energy. EMC is ultimately a system design issue. Part of the EMC performance is designed into or inherent in each component; another part is designed into or inherent in end product characteristics such as shielding, wiring, and layout; and, finally, a portion is a function of the interactions between all these parts. The design techniques presented below can enhance EMC performance in products that use Curtis control products.

Emissions

Signals with high frequency content can produce significant emissions if connected to a large enough radiating area (created by long wires spaced far apart). PWM drivers can contribute to RF emissions. Pulse width modulated square waves with fast rise and fall times are rich in harmonics. (Note: PWM drivers at 100% do not contribute to emissions.) The impact of these switching waveforms can be minimized by making the wires from the controller to the load as short as possible and by placing the load drive and return wires near each other.

For applications requiring very low emissions, the solution may involve enclosing the system, interconnect wires and loads together in one shielded box. Emissions can also couple to battery supply leads and circuit wires outside the box, so ferrite beads near the controller may also be required on these unshielded wires in some applications. It is best to keep the noisy signals as far as possible from sensitive wires.

Immunity

Immunity to radiated electric fields can be improved either by reducing overall circuit sensitivity or by keeping undesired signals away from this circuitry. The controller circuitry itself cannot be made less sensitive, since it must accurately detect and process low level signals from sensors such as the throttle potentiometer. Thus immunity is generally achieved by preventing the external RF energy from coupling into sensitive circuitry. This RF energy can get into the controller circuitry via conducted paths and radiated paths. Conducted paths are created by the wires connected to the controller. These wires act as antennas and the amount of RF energy coupled into them is generally proportional to their length. The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected.

The Curtis 1355 includes bypass capacitors on the printed circuit board's sensitive input signals to reduce the impact of this RF energy on the internal circuitry. In some applications, additional filtering in the form of ferrite beads may also be required on various wires to achieve desired performance levels. A full metal enclosure can also improve immunity by shielding the 1355 from outside RF energy.

ELECTROSTATIC DISCHARGE (ESD)

Curtis products, like most modern electronic devices, contain ESD-sensitive components, and it is therefore necessary to protect them from ESD (electrostatic discharge) damage. Most of the product's signal connections have protection for moderate ESD events, but must be protected from damage if higher levels exist in a particular application.

ESD immunity is achieved either by providing sufficient distance between conductors and the ESD source so that a discharge will not occur, or by providing an intentional path for the discharge current such that the circuit is isolated from the electric and magnetic fields produced by the discharge. In general the guidelines presented above for increasing radiated immunity will also provide increased ESD immunity.

It is usually easier to prevent the discharge from occurring than to divert the current path. A fundamental technique for ESD prevention is to provide adequately thick insulation between all metal conductors and the outside environment so that the voltage gradient does not exceed the threshold required for a discharge to occur. If the current diversion approach is used, all exposed metal components must be grounded. The shielded enclosure, if properly grounded, can be used to divert the discharge current; it should be noted that the location of holes and seams can have a significant impact on ESD suppression. If the enclosure is not grounded, the path of the discharge current becomes more complex and less predictable, especially if holes and seams are involved. Some experimentation may be required to optimize the selection and placement of holes, wires, and grounding paths. Careful attention must be paid to the control panel design so that it can tolerate a static discharge. MOV, transorbs, or other devices can be placed between B- and offending wires, plates, and touch points if ESD shock cannot be otherwise avoided.

APPENDIX B
PROGRAMMING DEVICES

Curtis programmers provide programming, diagnostic, and test capabilities for the 1355. The power for operating the programmer is supplied by the host controller via a 4-pin connector. When the programmer powers up, it gathers information from the controller.

Two types of programming devices are available: the 1314 PC Programming Station and the 1311/1313 handheld programmer. The Programming Station has the advantage of a large, easily read screen; on the other hand, the handheld programmer has the advantage of being more portable and hence convenient for making adjustments in the field.

Both programmers are available in User, Service, Dealer, and OEM versions. Each programmer can perform the actions available at its own level and the levels below that—a User-access programmer can operate at only the User level, whereas an OEM programmer has full access.

PC PROGRAMMING STATION (1314)

The Programming Station is an MS-Windows 32-bit application that runs on a standard Windows PC. Instructions for using the Programming Station are included with the software.

HANDHELD PROGRAMMER (1313)

The handheld programmer is functionally equivalent to the PC Programming Station; operating instructions are provided in the 1313 manual.

PROGRAMMER FUNCTIONS

Programmer functions include:

Parameter adjustment — provides access to the individual programmable parameters.

Monitoring — presents real-time values during vehicle operation; these include all inputs and outputs.

Diagnostics and troubleshooting — presents diagnostic information, and also a means to clear the fault history file.

Programming — allows you to save/restore custom parameter settings.

Favorites — allows you to create shortcuts to your frequently-used adjustable parameters and monitor variables.

APPENDIX C

SPECIFICATIONS

Table C-1 SPECIFICATIONS: 1355 MODULE

Nominal input voltage	24–36 V, 36–48 V
Electrical isolation to heatsink	500 Vac (minimum)
Storage ambient temperature range	-40°C to 85°C (-40°F to 185°F)
Operating ambient temp. range	-25°C to 50°C (-40°F to 122°F)
Enclosure protection rating	IP65 per IEC60529
Weight	1.23 kg
Dimensions (L×W×H)	165 × 120 × 72 mm 6.0 mm mounting hole ID
EMC	Designed to the requirements of EN12895:2000.
Safety	Designed to the requirements of EN 1175-1:1998+A1: 2010 and EN 13849-1:2008 Category 2.

			CURRENT RATING OF M1-M5 LOADS (ALL RUNNING TOGETHER)		CURRENT RATING OF ACTUATORS	
MODEL NUMBER	VOLTAGE	DESCRIPTION	10 s	1 hr	20 s	1 hr
1355-4001	24–36 V	Three full bridge actuators	100 A	40 A @100%PWM; 25 A @PWM%	10 A	5 A
1355-4101	24–36 V	Six digital inputs	100 A	40 A @100%PWM; 25 A @PWM%	n/a	n/a
1355-5001	36–48 V	Three full bridge actuators	70 A	35 A @100%PWM; 25 A @PWM%	10 A	5 A
1355-5101	36–48 V	Six digital inputs	70 A	35 A @100%PWM; 25 A @PWM%	n/a	n/a