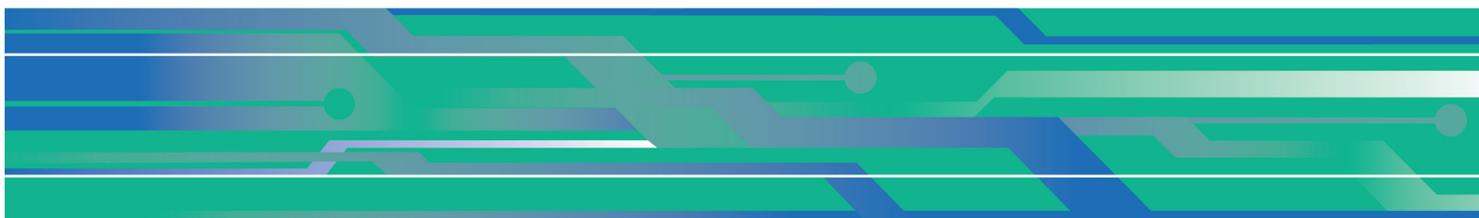# Manual

Model **1353**
CANopen Expansion Module

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⚠ Read Instructions Carefully!

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The Curtis Difference
You feel it when you drive it

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1 — OVERVIEW

The Curtis 1353 is a CANopen interface module with hydraulic system oriented functions, inputs, and outputs. It provides simple, flexible, and cost-effective control of up to nine proportional or on/off hydraulic valves. It can be used on internal combustion engines and electric vehicles.

The 1353 can extend the I/O capabilities of the Curtis VCL-driven system and enhance the systems that use Curtis AC controllers by providing additional I/O. Although the 1353 has specific features orienting it towards hydraulic valve control, the I/O and firmware are designed to give it the flexibility to be used in many generic applications, such as Mobile Elevating Work Platforms (MEWPs) and aerial lifts.

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, freezing, and dust. One section of the housing is aluminum which allows a simple method for heat-sinking the internal drivers.

Figure 1

Curtis 1353 CANopen interface module.

Features include:

- 9 high-frequency output drivers, which can also be used as active-high digital inputs.
- Closed loop constant current, constant voltage, or direct PWM control on each output.
- Built-in programmable dither control for hydraulic valves.
- Min/Max current and Ramp up/down time setting for driver outputs.
- Built-in coil flyback diodes.
- 6 analog inputs (0–15V), which can also be used as virtual digital inputs.

- 2 quadrature encoder inputs.
- 5V and 12V current limited power supplies.
- Optional serial port, for Curtis programmer or display.
- CANopen communication port controlled by two fixed PDO maps and programmable over SDOs.
- CAN Node ID selectable through digital inputs or virtual digital inputs.
- Software and hardware watchdog circuits ensure proper software operation.
- IP65-rated enclosure allows the 1353 to be mounted in multiple orientations, and protects it even in harsh environments.
- Status LEDs provide external monitoring.

DESCRIPTIONS OF KEY FEATURES

High Frequency Driver Outputs

The 1353 contains nine identical output drivers. These drivers can sink up to 3 amps each through an inductive load, with the total current limited to 18 A. Internal flyback diodes to B+ prevent voltage spikes. High frequency PWM (16 kHz) provides smooth current to the load.

Constant Current or Voltage Outputs

In Constant Current mode, the software runs a closed loop PI controller to provide an average constant current. This current is commanded over PDO as a 0–100% command based on the maximum current and minimum current settings with ramping features (set through SDO or a Curtis programmer).

Each output can also be programmed for Constant Voltage mode. In this mode, the battery voltage is monitored and the PWM command is corrected by a feed-forward controller to provide a constant average voltage commanded over the PDO (a 0–100% command based on the maximum voltage setting).

In addition, each output can also be programmed to provide a directly commanded PWM% output (Direct PWM mode) or shut off to be used as an input (Input Only mode).

Programmable Dither for Hydraulic Valves

Dither is a small variation in the command that keeps the seals of a proportional valve oiled. This lubrication allows the valve to move freely for accurate PV control. Dither is only active on drivers in Constant Current mode.

Min/Max Current

Max Current parameter sets the maximum allowed driver current through the load when driver command is 100%.

Most proportional valves need a non-zero closed current in order to start opening immediately. Min Current parameter sets the minimum driver current through the load when driver start (driver command > 0).

Ramp Up/Down

In 1353, each driver has a build-in ramping function that is applied to the command. There are separate values for ramping up and ramping down.

When driver is command on, the Ramp Up parameter sets the time (in ms) to go from the Min to Max current. When driver is command off, the Ramp Down parameter sets the time (in ms) to go from the Max to Min current.

Outputs as Active High Digital Inputs

Each output can be used as a digital input. Each input is digitally filtered to eliminate switch "bounce" or noise in the signal. There is a power resistor pull-down to B– at each input; therefore, these inputs are active high to B+.

Voltage Analog Inputs

The 1353 has six analog inputs that are scaled to read 0–15 volts. The analog channels are read by a 12-bit ADC, resulting in about 3.66 millivolt resolution. Independently adjustable filters ensure a smooth signal.

Resistive Sensor Inputs

Each analog input can be used with resistive sensors, such as RTDs (Resistive Temperature Devices).

Virtual Digital Inputs

The six analog inputs are also sensed and decoded as if they were digital inputs. A unique feature of these digital inputs is that the active high/low thresholds are completely programmable. Thus, these inputs can be used with analog sensors to detect conditions like over/under pressure, high/low level points, etc.

Encoder Interface

The 1353 has two quadrature encoder inputs, which share with the Analog 1–4 pins. The 1353 can detect an open fault on the encoder input wire.

CAN Interface

The 1353 is CANopen compliant, responding to the standard NMT, PDO, and SDO communications as well as the DS301-required identity and standard objects. The Curtis CANopen extensions allow additional features, such as OEM and User default configurations and time-stamped fault logging.

PDO Map

The 1353 can receive two PDOs and respond with two PDOs. These PDOs are fixed, simplifying the VCL interface to the module. All programmable parameters and viewable values within the 1353 are accessible by SDOs or with a Curtis programmer.

Familiarity with your Curtis 1353 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 1353 module are shown in Figure 2. The module should be mounted using two #10 or M5 screws.

CAUTION

Care should be taken to prevent contaminating the connector area before the mating 23-pin connector is installed. Once the system is plugged together, the 1353 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.

Figure 2

Mounting dimensions, Curtis 1353 expansion module.

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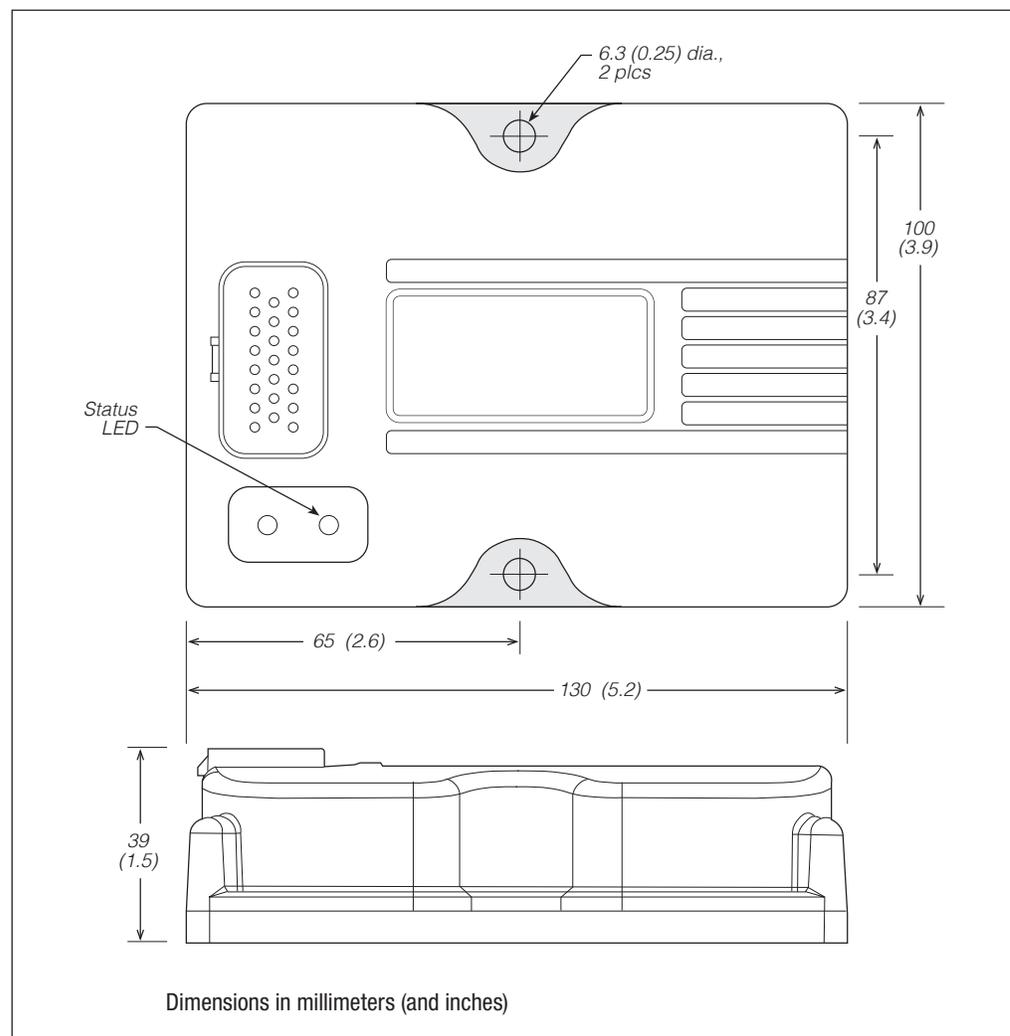
If the outputs will be used at or near their maximum ratings, it is recommended that the module be mounted to a good heatsinking surface, such as an aluminum plate.

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 1353 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.

CONNECTIONS

All connections are made through the 23-pin AMPSEAL connector. The mating plug housing is AMP p/n 770680-1, and the contact pins are AMP p/n 770520-3. The connector will accept 20 to 16 AWG wire with a 1.7 to 2.7 mm diameter thin-wall insulation.

CAUTION

Note that the 1353's pins are not sealed until the mating connector is fully engaged and locked. The cable harness connector has a silicone rubber seal that is an integral part of the module's sealing.

The 23 individual pins are characterized in Table 1.
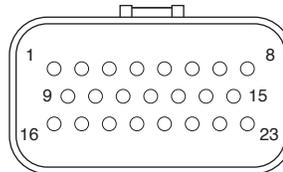
Wiring recommendations

Power and ground (Pins 1, 2, 9)

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. To prevent overheating these pins, the wire gauge must be sufficient to carry the continuous and maximum loads that will be seen at each pin.

Driver outputs (Pins 15–23)

The driver outputs produce high frequency (16 kHz) pulse waves that can radiate RFI noise. The wire from the module to the load should be kept short and routed with the return wire back to the module.

CANbus (Pins 7 and 8)

It is recommended that the CAN wires be run as a twisted pair. However, many successful applications at 125 kbit/s are run without twisting, simply using two lines bundled in with the rest of the low current wiring. CAN wiring should be kept away from the high current cables and cross it at right angles when necessary. If the 1353 is at the end of the CANbus, the bus needs to be terminated by externally wiring a 120Ω ½W resistor across CAN High and CAN Low.

All other low current wiring (Pins 3, 5–6, 10–14)

The remaining low current wiring should be run according to standard practices. Running low current wiring next to the high current wiring should always be avoided.

Table 1 Connector Pinout

Pin	Name	Description
1	B+	Battery positive.
2	B–	Battery negative.
3	+5 V	Regulated low power +5 V output.
4	I/O GND	Input and output ground reference.
5	Analog Input 4 / Encoder 2B	Voltage or Resistive Input4 & Quadrature Encoder Input Phase 2B.
6	Analog Input 3 / Encoder 2A	Voltage or Resistive Input3 & Quadrature Encoder Input Phase 2A.
7	CAN H	CANbus High communication line.
8	CAN L	CANbus Low communication line.
9	B–	Redundant battery negative (for high current drive).
10	+12 V	Unregulated low power +12 V output.
11	Analog Input 5 / Serial Tx	Voltage or Resistive Input5 & serial transmit.
12	Analog Input 6 / Serial Rx	Voltage or Resistive Input6 & serial receive.
13	Analog Input 2 / Encoder 1B	Voltage or Resistive Input2 & Quadrature Encoder Input Phase 1B.
14	Analog Input 1 / Encoder 1A	Voltage or Resistive Input1 & Quadrature Encoder Input Phase 1A.
15	Input/Output 9	Active high Input9 & high power PWM active low Output9.
16	Input/Output 8	Active high Input8 & high power PWM active low Output8.
17	Input/Output 7	Active high Input7 & high power PWM active low Output7.
18	Input/Output 6	Active high Input6 & high power PWM active low Output6.
19	Input/Output 5	Active high Input5 & high power PWM active low Output5.
20	Input/Output 3	Active high Input4 & high power PWM active low Output4.
21	Input/Output 3	Active high Input3 & high power PWM active low Output3.
22	Input/Output 2	Active high Input2 & high power PWM active low Output2.
23	Input/Output 1	Active high Input1 & high power PWM active low Output1.

WIRING: BASIC CONFIGURATION

A basic wiring diagram is shown in Figure 3, and described below. The diagram shows the standard power and battery connections, as well as some basic uses for the inputs and outputs.
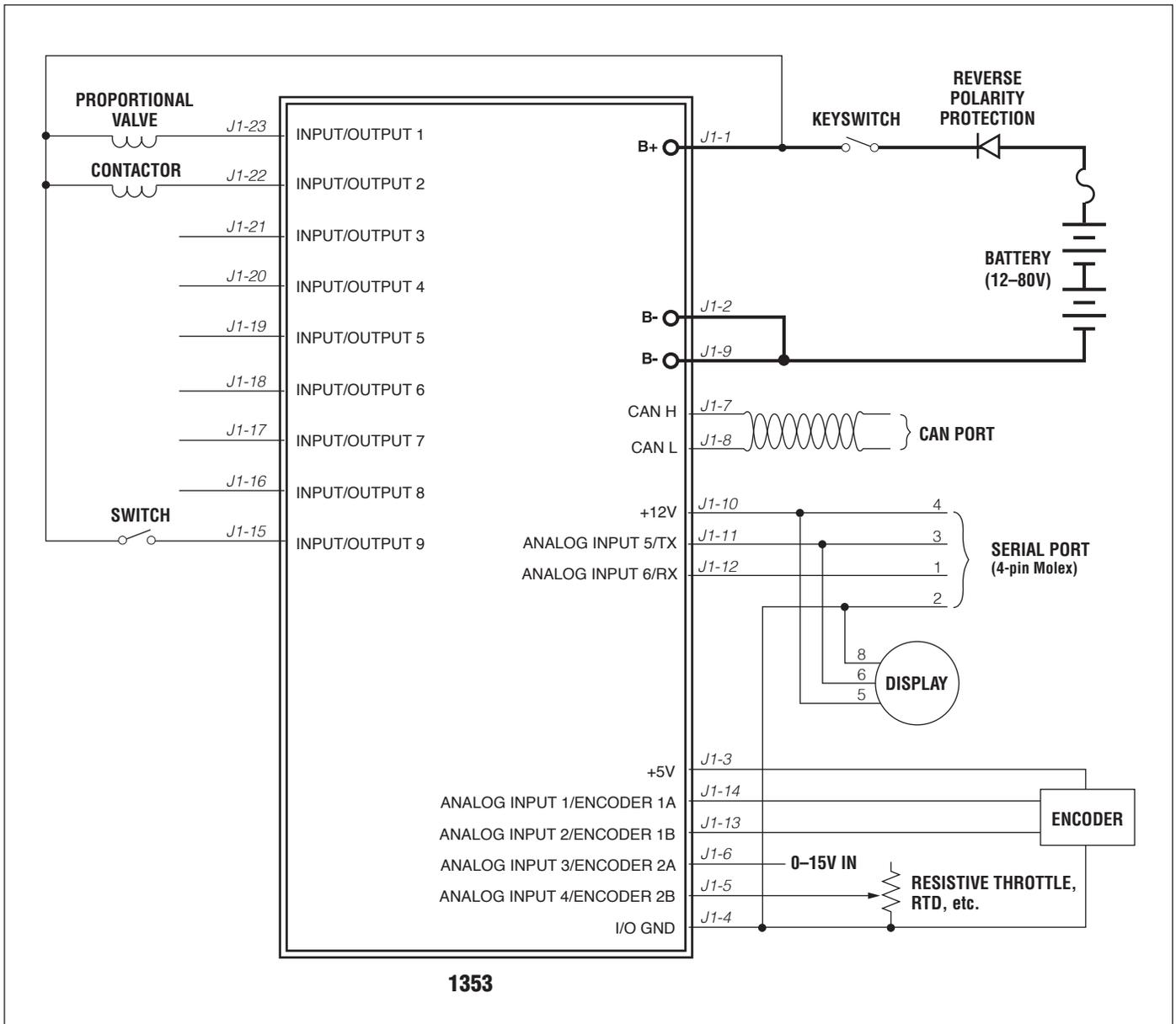
Figure 3

Basic wiring diagram, Curtis 1353 CANopen expansion module.

Power Connection

The battery is connected to the module's **B+** pin though a fuse, a diode, and a keyswitch. The fuse protects the wiring in the event of a short or failure. The return path of the coils is also brought back to the B+ pin to utilize the flyback diodes connected inside the 1353 between B+ and each driver output.

The keyswitch is used to turn on the system. When the keyswitch is closed, B+ goes high and the 1353's power supply brings up the module.

Driver Outputs

All nine drivers (Pins 15–23) are identical. Each is capable of driving a closed-loop current-controlled proportional valve or a voltage-controlled contactor. Each driver has independent mode, max, and dither settings.

These are high-power drivers. The internal impedance to ground will cause leakage current to flow through the output even when the output driver is off. This leakage current can be enough (>2 mA) to light high-efficiency LEDs.

In the wiring diagram, the output at Pin 23 is shown driving a proportional valve coil. This driver is programmed for Constant Current mode and would have some Dither applied.

The second output shown (Pin 22) is driving a basic contactor coil. This output is in the Constant Voltage mode and can be set to run at a lower voltage than the nominal battery voltage.

Switch Inputs

All the outputs can be used as Active High inputs ("On" when connected to B+). It is important that the output command be set to 0% for each input used or a direct short from B+ to B– will be generated when the driver is pulsed On, which could damage the FET driver. In the wiring diagram, I/O 9 (Pin 15) is shown as an Active High input switching to B+.

Analog Inputs

The fourth analog input (Pin 5) is shown being used with an RTD. This requires enabling the Analog Input 4 pull-up, which allows the input to measure resistive sensors.

CANbus

The 1353 has an internal 1 kΩ bus termination resistor. This internal impedance matches the system requirements for a mid-line connection or short stub connection. If the 1353 is to be used at the end of the CANbus, an external 120 Ω ½W resistor must be added externally across the CAN H and CAN L lines at or near the module to provide proper termination. The higher the bit rate (i.e., the higher the baud), the more critical this becomes. The 1353 can communicate up to 1 Mbit/s on a properly terminated/wired bus.

WIRING: APPLICATION EXAMPLE

The wiring diagram in Figure 4 provides an example of proportional valve control for an electric forklift.
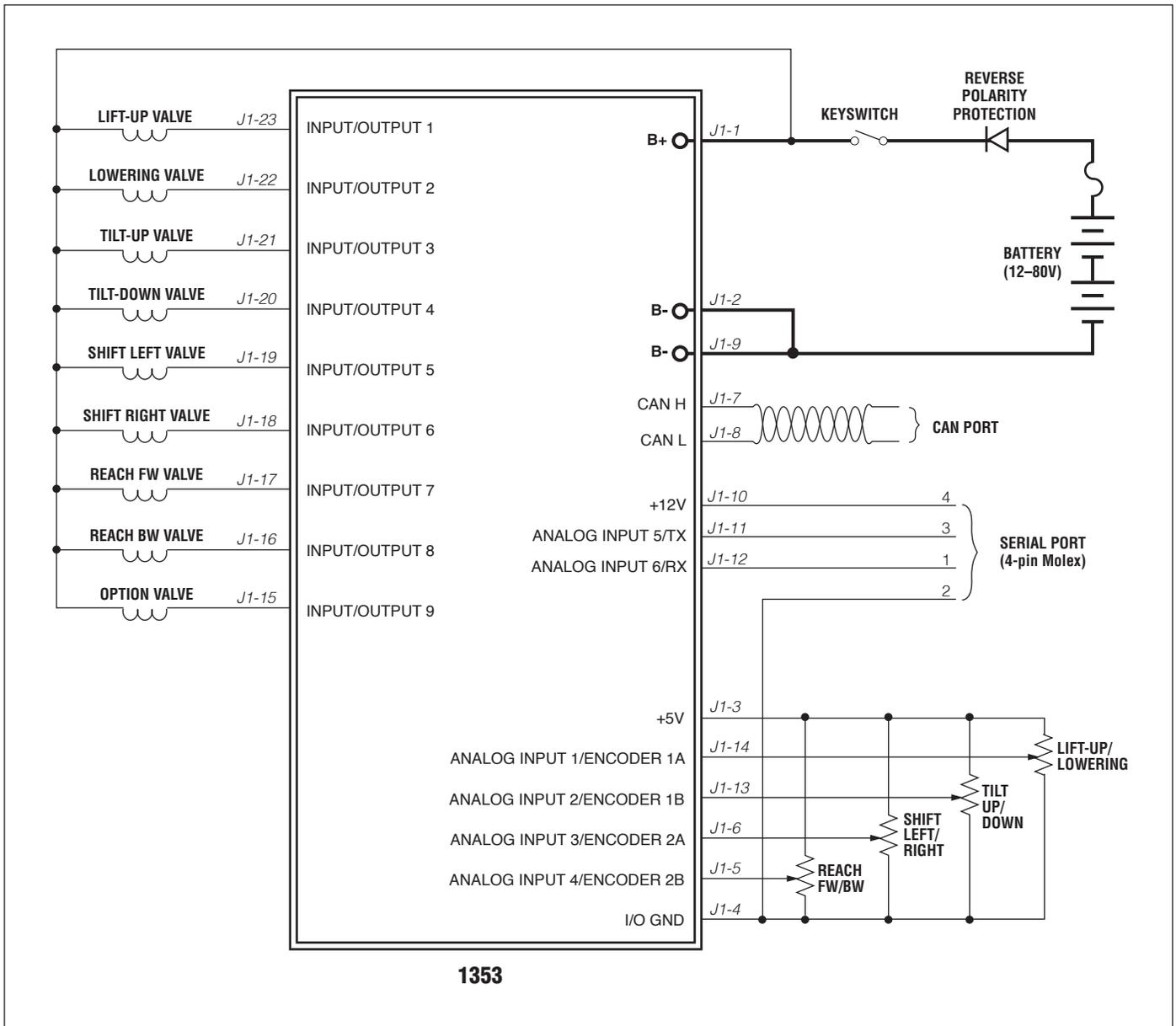

Figure 4

*Application example, Curtis 1353 CANopen expansion module.*

INPUT/OUTPUT SIGNAL SPECIFICATIONS

The input/output signals wired to the 23-pin connector can be grouped by type as follows; their electrical characteristics are discussed below.

- driver outputs
- digital inputs
- analog inputs with virtual digital input
- encoder inputs
- serial port
- auxiliary power supplies
- CANbus interface

Driver Outputs

The 1353 contains nine identical driver outputs. These outputs have all the features necessary to drive proportional valves as well as many other inductive and non-inductive loads. A variable amount of dither (fixed frequency command "jitter") can be added to the PWM to prevent proportional valves from sticking in place.
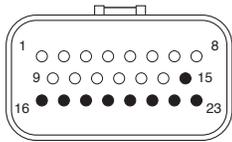
DRIVER OUTPUT SPECIFICATIONS

Signal Name	Pin	Max Current	Impedance	Frequency
Input/Output 9	15	*Each driver:* 3 amps *All 9 total:* 18 amps	*12 – 36 V models:* 10 kΩ pulldown to B– *36 – 80 V models:* 47 kΩ pulldown to B–	*All models:* 16 kHz 0–100% duty cycle
Input/Output 8	16			
Input/Output 7	17			
Input/Output 6	18			
Input/Output 5	19			
Input/Output 4	20			
Input/Output 3	21			
Input/Output 2	22			
Input/Output 1	23			

The drivers can be set for Constant Current, Constant Voltage, or Direct PWM control mode.

In *Constant Current* mode, the driver command of 0 to 100% is interpreted as a current from 0 to Max Output setting (up to 3 amps). Internal current shunts are measured and fed back to a closed loop PI controller to provide a steady current over changing loads and supply voltages.

In *Constant Voltage* mode, the driver command of 0 to 100% is interpreted as a voltage from 0 to Max Output (up to 80 volts). The battery voltage is constantly monitored and fed back to a closed loop PI controller to provide a steady voltage, compensating for battery droop and discharge. If the command is higher than the driver can output, the PWM will max out at 100%.

In *Direct PWM* mode, the driver command of 0 to 100% is directly output on the driver.

Each driver is monitored and will detect a short in the load, a failed internal driver FET, and/or an open in the load wiring. At near 0% and 100% PWM, it is not possible to discern each fault and some faults will not be detected.

If the driver outputs are connected to inductive loads, the coil should have a return line to the B+ pin of the 1353. This connection provides a path for the internal freewheel diodes to clamp the turn-off spike. Failure to make this connection with inductive loads can cause permanent damage to the 1353 as well as propagate failures of other electronics in the system due to the high voltage spike caused when an inductive load turns off without a freewheel path.

Digital Inputs

The nine digital I/O lines can also be used as digital (on/off) inputs. Normal "on" connection is direct to B+; "off" is direct to B–. Input will pull low (off) if no connection is made.
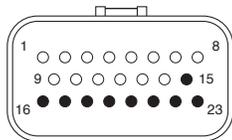
DIGITAL INPUT SPECFICATIONS

Signal Name	Pin	Logic Threshold	Input Impedance
Input/Output 9	15	*All models:* Low = 1.6V High = 4.0V	*12 – 36 V models:* about 10 kΩ *36 – 80 V models:* about 47 kΩ
Input/Output 8	16		
Input/Output 7	17		
Input/Output 6	18		
Input/Output 5	19		
Input/Output 4	20		
Input/Output 3	21		
Input/Output 2	22		
Input/Output 1	23		

Because these nine lines can also be used as driver outputs, it is important to ensure that Operation Mode is set appropriately for each line. For each pin that will be used as a digital input, Operation Mode must be set to Input Only (see page 31). Otherwise, a direct short from the battery through the internal driver FET will occur when the input is switched high and the FET is turned on.

Analog Inputs

The 1353 has four or six 0 – 15 V analog inputs, depending on the model. These inputs are scaled down by 5.76, clamped to 3.3 V, and read by a 12-bit ADC internal to the MCU.
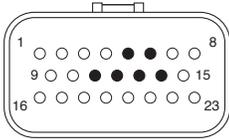
ANALOG INPUT SPECIFICATIONS

Signal Name	Pin	Voltage	Input Impedance	Protected Voltage Range
Analog Input 1	14	*Nominal input voltage: 0–15V* *Input Max. reverse voltage: –1.7V*	*Voltage Input Type: ~21 KΩ* *Resistance input type: ~1 KΩ*	–1 V to B+
Analog Input 2	13			
Analog Input 3	6			
Analog Input 4	5			
Analog Input 5*	11			–0.3 to 12 V
Analog Input 6*	12			

* Can be used as serial port on 1353-4101 and –6101.

The maximum resistive input on each analog input is 7.5 kΩ. The resistive or voltage type of analog input can be selected by a Curtis programmer (1313/1314) or CAN SDO message.

These six analog inputs can also be used as digital inputs. A unique feature of these digital inputs is that the active high/low thresholds are completely programmable. Thus, these inputs can be used with analog sensors to detect conditions like over/under pressure, high/low level points, etc.

Encoder Inputs

Analog Inputs 1 – 4 can be configured as two encoder inputs (Encoder 1A&1B and Encoder 2A&2B). These standard quadrature encoder inputs accept open collector encoders with pull-up resistors. The encoders can be powered from the +5V supply (Pin 3) or the +12V supply (Pin 10) while using the I/O GND as a common.
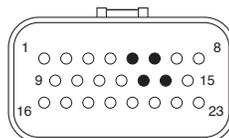
ENCODER INPUTS SPECIFICATIONS

Encoder Phase	Vth LO	Vth HI	Frequency Max	Input Impedance	Protected Voltage Range
A	1.0 V	2.2 V	15 kHz	1KΩ (internal pull-up to +4.4 V)	–1 V to B+
B					

Serial Port   *(Models 1353-4101 and 1353-6101 only)*

On selected models, Pins 11 & 12 can be configured as a serial port or as analog inputs via SDO. The Curtis programmer can connect to this serial port using pins 11 & 12 along with I/O GND (Pin 4) and +12V supply (Pin 10); see wiring diagram, Figure 3. The Curtis Model 840 also can be connected to this port.

SERIAL PORT SPECIFICATIONS

Signal Name	Pin	Supported Protocol/Devices	Data Rate	Protected Voltage Range
TX	11	1313 Handheld Programmer, 1314 PC Programming Station. Curtis 840 Display	As required, 9.6 to 56kbps	−0.3 V to 12 V
RX	12			

Auxiliary Power Supplies

The 1353 provides +12V and +5V auxiliary output power for low power circuits such as a fingertip joystick, electronic throttle, Curtis programmer, or remote I/O boards. The return line for these low power circuits is I/O GND (Pin 4). The maximum total combined output current is 200 mA.
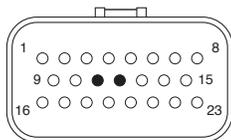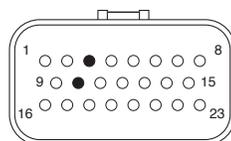
AUXILIARY POWER SUPPLY SPECIFICATIONS

Signal Name	Pin	V OUT	V OUT Tolerance	I OUT (Max)	Ripple/Noise
−12 V	10	12 V	10 %	−100 mA	2%
−5 V	3	5 V	5 %	−100 mA	2%

CANbus Interface

The CANbus interface will comply with CAN2.0B, active from 50 kbit/s to 1Mbsp communication rate.

The 1353 will be terminated by an internal 1 kΩ resistor across the CAN High and Low communication pins. This assumes a mid-truck connection (not end-of-line). If the 1353 is placed at the end of the communication lines, an external 120 Ω, ½ W resistor must be added across the lines.
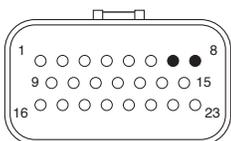
Power

The power pins are each capable of carrying up to 9 A. Every application must use B+ (Pin 1) and one or both of the B− connections (Pins 2, 9).

Since the 1353's nine drivers can sink a maximum combined load of 18 A, you will need to determine the application's maximum total loading on B−. To prevent the pin from overheating, the proper wire gauge must be used and, if the load is greater than 9 A, both B− pins connections are required.

If it is determined that both B− pins are required, you must also determine the load on B+. This requires either knowledge of the expected PWM or actual in-application measurements. The combined average current recirculating through the B+ pin cannot exceed 9 A. This can be an issue if the inductive loads are specified at a lower voltage than the battery supply as the applied PWM would normally be reduced so as not to exceed the average applied voltage or current. The lower PWM in turn raises the average current flowing theourgh the B+ pin as the load current recirculates for a greater portion of the PWM period.
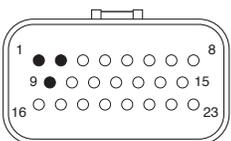
3 — CANOPEN COMMUNICATIONS

The 1353 adheres to the industry standard CANopen communication protocol and thus will easily connect into many CAN systems, including those using the Curtis AC and Vehicle System controllers (1232/34/36/38, 1298, and 1310). Any CANopen-compatible master can be programmed to control the 1353.

The 1353 receives two PDOs and responds with two PDOs. These PDOs are fixed, simplifying the VCL interface to the controller. All programmable parameters and monitor parameters are accessible by standard SDO transfer.

The time between incoming PDOs is monitored and if excessive, will flag a fault. This allows the 1353 to know that the system is still under master control. The 1353 also produces Heartbeat and Error messages, which is the CiA-preferred safety and security method.

MINIMUM STATE MACHINE

The 1353 will run the CANopen minimum state machine as defined by CiA. The CANopen minimum state machine has four defined states: Initialization, Pre-Operational, Operational, and Stopped.
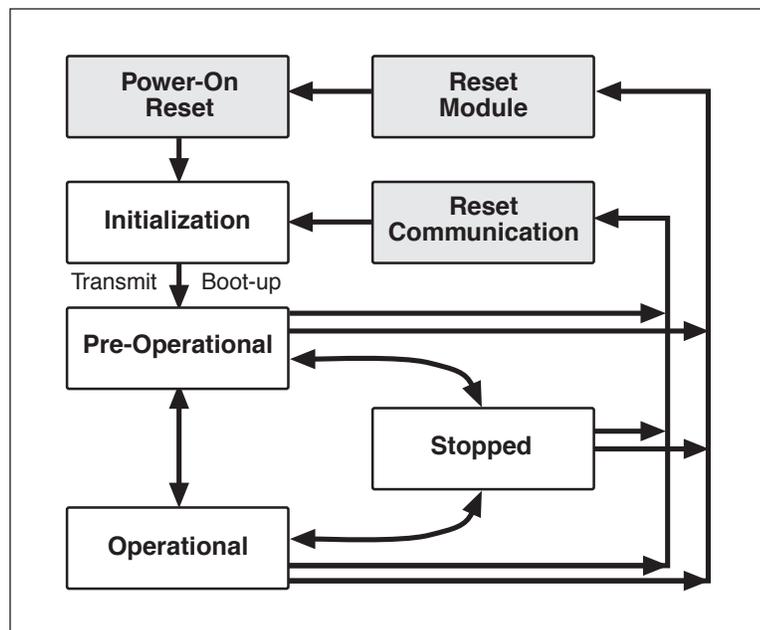
When the 1353 powers up, it goes to the Initialization state; this is also known as the Boot-up state. No CAN communications from the 1353 are transmitted in this state although the 1353 listens to the CANbus. When the 1353 has completed its startup and self-tests, it issues an initialization heartbeat message and automatically goes to the Pre-Operational state.

In the Pre-Operational state, the 1353 can receive and respond to SDOs and NMT commands, and will send its heartbeat. It will not receive or send PDOs. When the master issues a goto Operational State NMT command, the 1353 will go to full normal operation.

In the Operational state, the 1353 will start receiving and responding to PDOs and process all other necessary CANopen messages.

If the master sends a Stop NMT command or the 1353 detects an internal fault, the 1353 will go to the Stopped state. In the Stopped state the 1353 will listen for NMTs and produce its heartbeat message only. PDOs and SDOs (including any timeouts) are ignored.

At any point, if the master sends a Reset Communication or Reset Module (warm boot), the 1353 will go to the Initialization state as if there were a power-cycle.

Baud Rates

The 1353 runs at one of the seven selectable baud rates: 50 kbit/s, 100 kbit/s, 125 kbit/s, 250 kbit/s, 500 kbit/s, 800 kbit/s, and 1 Mbit/s. The baud rate can be changed by a Curtis programmer or by an SDO. Changes in the baud rate require an NMT reset or KSI cycle.

CAN Node ID

In 1353, CAN Node ID can be selected from two parameters (Node ID Low and Node ID High) and be determined by a wired input source. The parameter of Node ID Source selects which source is used (see table below for detail). If no source is used, set this parameter to 0.

If Node ID Source is zero, or if selected Node ID Source is non-zero and the input of this Node ID Source is low when 1353 power on, the Node ID Low parameter will be applied as the 1353 CAN Node ID.

If selected Node ID Source is non-zero, and the input of this Node ID Source is high when 1353 power on, the Node ID High parameter will be applied as 1353 CAN Node ID.

Node ID Source	Description
0	No source input. Parameter Node ID Low is the default CAN Node ID
1	Digital input1 is used as the Node ID Source
2	Digital input2 is used as the Node ID Source
3	Digital input3 is used as the Node ID Source
4	Digital input4 is used as the Node ID Source
5	Digital input5 is used as the Node ID Source
6	Digital input6 is used as the Node ID Source
7	Digital input7 is used as the Node ID Source
8	Digital input8 is used as the Node ID Source
9	Digital input9 is used as the Node ID Source
10	Virtual digital input1 is used as the Node ID Source
11	Virtual digital input2 is used as the Node ID Source
12	Virtual digital input3 is used as the Node ID Source
13	Virtual digital input4 is used as the Node ID Source
14	Virtual digital input5 is used as the Node ID Source
15	Virtual digital input6 is used as the Node ID Source

Changes to the node ID require an NMT reset or KSI cycle.

1353 will issue "Node ID Source Fault" when Node ID Source is set with conflict. The following table describes the detail for each source.

Node ID Source	Description
0	NA
1	Input/Output1 isn't set to input mode.
2	Input/Output2 isn't set to input mode.
3	Input/Output3 isn't set to input mode.
4	Input/Output4 isn't set to input mode.
5	Input/Output5 isn't set to input mode.
6	Input/Output6 isn't set to input mode.
7	Input/Output7 isn't set to input mode.
8	Input/Output8 isn't set to input mode.
9	Input/Output9 isn't set to input mode.
10	Encoder1 function is enabled.
11	
12	Encoder2 function is enabled.
13	
14	N/A
15	

Standard Message Identifiers

The standard message types are defined within a 4-bit field in the COB ID (**C**ommunication **OB**ject **ID**entification). Consequently, there are 16 possible standard message types. The values for Curtis products are:

Generic Type	Message Identifier	Value (binary – hex)
NMT	NMT	0000 – 0x0
EMERGENCY	SYNC_ERR	0001 – 0x1
PDO	PDO1_MISO	0011 – 0x3
	PDO1_MOSI	0100 – 0x4
	PDO2_MISO	0101 – 0x5
	PDO2_MOSI	0110 – 0x6
SDO	SDO-MISO	1011 – 0xB
	SDO_MOSI	1100 – 0xC
HEARTBEAT	NODE	1110 – 0xE

These types and values comply with the CANopen spec and are used to invoke standard transfer or information across the CANbus.

Identifiers built using standard message types consist of three fields. The four upper bits hold the message type. The Node ID is in the bottom 7 bits.

Below is the CANopen-compliant Curtis standard organization of the COB-ID.

11	10	9	8	7	6	5	4	3	2	1

←— Message Type —→ ←————————— Node ID —————————→
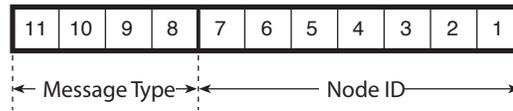
NMT messages have the highest priority of the standard message types, and the heartbeat has the lowest priority.

NMT MESSAGES

NMT (**N**etwork **M**anagement **T**ransmission) messages are the highest priority message available. The NMT message puts the 1353 into a specific device state. These messages have 2 bytes of data sent by the master; the slave does not respond with any data to an NMT.

The 1353 state value can be queried over the CANbus using an SDO. The device state value is also transmitted with each heartbeat message.

Value	Device State
0	Initialization (or "boot-up")
4	Stopped
5	Operational
127	Pre-Operational

The NMT message identifier consists of the standard message type, NMT, in the top four bits. The bottom seven bits must be set to zero.

The first data byte of the NMT command is the command specifier. The 1353 will respond to the following commands.

Value	Command Specifier
0x01	Enter the Operational state
0x02	Enter the Stopped state
0x80	Enter the Pre-Operational state
0x81	Reset the 1353 (warm boot)
0x82	Reset the CANbus

The second byte of the NMT command defines whether this NMT is for all slaves on the bus (data byte = 0x00) or for a specific node (data byte = Node ID of the 1353).

EMERGENCY MESSAGES

Emergency messages are the second highest priority in CANopen and the highest priority that a slave (like the 1353) can transmit. These messages are sent sporadically whenever there is a change of state in the 1353's fault flags.

To prevent fast-changing fault bits from flooding the bus, a minimum Emergency Rate between messages can be programmed by Curtis programmer or SDO.

An Emergency Message consists of 8 data bytes.

Data bytes 1 and 2 define the error category.

Data byte 3 is the CANopen-required error register. Curtis products define this as 0x01 if there is a fault present and 0x00 when this fault is clear.

Data bytes 4 through 8 define the specific fault. The 1353 will place the current 24-bit hour meter into data bytes 4 through 6.

Bytes 7 and 8 are not used by the 1353 and are always 0x0000.

The emergency message format indicating an error is shown below.

byte 1					byte 8
Curtis Code	0xFF	0x01	16-bit field	0x00	0x0000
Error Code			*Hour Meter*		

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 1353 is in the Pre-Operational state, the next 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.

4 — PDO COMMUNICATIONS

The 1353 is controlled and monitored through four fixed communication packets. Each data packet contains 8 bytes. Two are received by the 1353 from another module (usually the system master) and in response, the 1353 sends out its packet of data. CANopen calls these packets **P**rocess **D**ata **O**bjects (PDOs). PDO messages have a medium priority.

The PDO communication packets conserve bus bandwidth by bundling the values of a group of objects into a single message. The content of these PDOs is fixed, thus simplifying the interface.

The 1353 normally 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 1353 will flag a fault and disable all output drivers. If the PDO Timeout parameter is set to 0, the timeout fault is disabled and the 1353 will respond to any PDO incoming at any rate without faulting.

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

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Output 1 Command	Output 2 Command	Output 3 Command	Output 4 Command	Output 5 Command	Output 6 Command	Output 7 Command	Output 8 Command

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

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Output 9 Command	BDI (0–100%)	[Reserved]	[Reserved]	[Reserved]	[Reserved]	[Reserved]	[Reserved]

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
Input 1–8 Status	Input 9 Status	6 Virtual Digital Inputs	[Reserved]	Analog Input 5 Low Byte	Analog Input 5 High Byte	Analog Input 6 Low Byte	Analog Input 6 High Byte

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
Analog Input 1 Low Byte (Encoder1 byte1)	Analog Input 1 High Byte (Encoder1 byte2)	Analog Input 2 Low Byte (Encoder1 byte3)	Analog Input 2 High Byte (Encoder1 byte4)	Analog Input 3 Low Byte (Encoder2 byte1)	Analog Input 3 High Byte (Encoder2 byte2)	Analog Input 4 Low Byte (Encoder2 byte3)	Analog Input 4 High Byte (Encoder2 byte4)

Output Command Bytes

The drivers are closed-loop controlled, either for current or voltage. This byte sets the output command as a percent of the programmed output limit value: 0–255 = 0%–100%.

BDI

The 1353 can get the BDI value from PDO2-MOSI. This byte is a percent of the battery state of discharge: 0–100 = 0–100%.

Inputs 1–9 Status Bytes

The 1353 monitors the inputs connected to the nine drivers. The status of these inputs appears in this bit with Input 1 being the LSB of Byte 1 and Input 8 being the MSB of PDO1-MISO Byte 1 and Input 9 being the LSB of PDO1-MISO Byte 2. A status of 1 (bit set) indicates the input is active (pulled high to B+). The upper 7 bits of Byte 2 are unused and set to 0.

Virtual Digital Inputs Byte

The analog inputs also produce a "virtual" digital input response. The lower 6 bits of PDO1-MISO Byte 3 represent the status of the six virtual inputs associated with the six analog inputs; Analog Input 1 is the LSB. The upper 2 bits are unused and set to 0. If the input is above the High Threshold (set using a Curtis programmer or an SDO) the bit will be set to 1. If the input is below the Low Threshold, it will be set to 0. If the input is between the two thresholds, the bit will retain its previous state.

Analog Input High/Low Bytes

If the voltage input type is enabled, the 0–15V scale is returned as 0.01 volt per count. For example, 15V is returned as 1500. This requires 2 bytes of the PDO data packet per input.

If the resistive input type is enabled, the value will be returned as ohms, up to 7.5 kΩ. If the pin is open, the value will be returned as 0xFFFF (65535), which will be interpreted as infinity (open pin).

When analog input pairs (1&2 or 3&4) are configured as encoder input, the relative PDO bytes will carry the pulse count, RPM value, or position value of the encoder. The encoder output can be configured as the following types, using a Curtis programmer or an SDO.

Pulse Count type

In this type, PDO will output the number of the encoder pulses accumulated. The value is signed and thus can count up to $2^{29}-1$ or down to -2^{29} at which point it will roll back to zero. In PDO2-MISO, for Encoder 1, byte 1 is the lowest byte of pulse count and byte 4 is the highest byte. For Encoder 2, byte 5 is the lowest byte of pulse count and byte 8 is the highest byte.

RPM type

In this type, PDO will send the RPM value (unit in revolutions per minute). In PDO2-MISO, for Encoder 1, byte 1 is the lowest byte of RPM and byte 2 is the highest byte. For Encoder 2, byte 5 is the lowest byte of RPM and byte 6 is the highest byte. Bytes 3&4 and bytes 7&8 are not used and always return 0.

Position type

In this type, PDO will send the position value (unit in mm). In PDO2-MISO, for Encoder 1, byte 1 is the lowest byte of position and byte 2 is the highest byte. For Encoder 2, byte 5 is the lowest byte of position and byte 6 is the highest byte. Bytes 3&4 and bytes 7&8 are not used and always return 0.

5 — SDO COMMUNICATIONS

CANopen uses **S**ervice **D**ata **O**bjects (SDOs) to change and view all internal parameters, or "objects." The SDO is an 8-byte packet that contains the address and sub-address of the parameter in question, whether to read or write the parameter, and the parameter data (if it is a write command). SDOs are sent infrequently and have a low priority on the CANbus.

SDOs are designed for sporadic and occasional use during normal runtime operation. There are two types of SDOs: expedited and block transfer. The 1353 does not support large file uploads or downloads (using the block transfer), so all the SDOs used by the 1353 are expedited SDOs.

The SDOs in the 1353 are used to set up and parameterize the module. They are also used to retrieve basic module information (such as version or manufacture date), review the fault log, and monitor a few key internal variables (mostly for system debug purposes).

SDO Master Request (SDO-MOSI)

An SDO transfer always starts with a request message from the master. Each SDO request message consists of one control byte, a two-byte CAN Object index, a one-byte CAN Object sub-index, and up to 4 bytes of valid data. This format is CANopen compliant.

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

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Control	CAN Object Index		Sub-index	Data	Data	Data	Data

The first data byte contains R/W message control information.

Action	Byte 1 Value
Read	0x4x
Write	0x2x

The next two data bytes hold the CAN Object index. The LSB of the index appears first, in byte 2, and the MSB appears in byte 3. For example, if the index is 0x3021, byte 2 holds the 0x21 and byte 3 holds the 0x30.

Data byte 4 holds the CAN Object sub-index. When there is only one instance of a parameter or value type, this value is 0. If there are several related parameters or values, the sub-index is used.

The last four data bytes hold the data that is to be transferred. In the case of a single-byte transfer, the data is placed into data byte 5, with bytes 6 through 8 being undefined (set to 0). In the case of a 16-bit transfer, the lower 8 bits appear in data byte 5 and the upper 8 bits appear in data byte 6; bytes 7 and 8 are undefined (set to 0). The case of a 32-bit transfer follows the same strategy, with the least significant byte placed in data byte 5 and the most significant byte placed in data byte 8.

SDO 1353 Response (SDO-MISO)

An SDO request is always acknowledged with a response message from the 1353. The 1353 can issue two kinds of response messages: a normal response or, in case of an error in the request SDO, an Abort SDO Transfer message.

SDO-MOSI *(sent by the 1353 in response to the system master)*

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Control	CAN Object Index		Sub-index	Data: either the requested Read values, or the actual Write values, or an error code			

The first data byte of the response contains an acknowledge code, which depends on the type of transfer that was initially requested.

Action	Byte 1 Value
Read Response	0x42
Write Acknowledge	0x60
Abort SDO	0x80

Data bytes 2, 3, and 4 hold the CAN Object index and sub-index of the request SDO.

If the SDO was a read command (a request for data from the 1353), data bytes 5 through 8 will be filled with the requested values, with the LSB in data byte 5 and the next least significant in byte 6 and so forth. All unused bytes are set to 0.

If the SDO was a write command, data bytes 5 through 8 will return the **actual** value written in bytes 5 – 8. In this way, if the 1353 needs to limit or round-down the SDO write request, the master will know—because the return value will be different than the sent value.

If the SDO-MOSI did not properly read or tried to access a parameter improperly, an Abort SDO Transfer will be sent. Data bytes 5 through 8 will be filled with a 32-bit error code.

> 0x06020000 = Object does not exist
>
> 0x06010002 = Attempt to write to a read only object.

TYPES OF SDO OBJECTS

Three types of SDO objects are described in the following pages: *Communications Profile Objects* (address range 0x1000), *Device Parameter Objects* (address range 0x3000), and *Device Monitor Objects* (address range 0x3100).

COMMUNICATION PROFILE OBJECTS

The objects found in the 0x1000 CAN Object address range are shown below in Table 2.

Table 2 Communication Profile Object Dictionary

Name	Access	Index	Sub-index	Range *Can Value*	Description
Device Type	RO	0x1000	0x00	0x00000000	Predefined type of CAN module (I/O).
Error Register	RO	0x1001	0x00	0 or 1	= 1 if there is an error = 0 if there are no errors
Manufacturer's Status Register 1	RO	0x1002	0x00	*4 bytes*	The value of Status Register 1. See Table 2a for more details.
Manufacturer's Status Register 2	RO	0x1002	0x01	*4 bytes*	The value of Status Register 2. See Table 2a for more details.
Fault Log	RW	0x1003	0x00	0x10	Length of this object. Clear fault log by writing 0 into this address.
	RO		0x01–0x10	*4 bytes*	Contains an array of 16 fault code and time stamps as reported by the Emergency Message.
Node ID Low	RW	0x100B	0x00	0x01 – 0x7F	If Node ID Source is zero, or if selected Node ID Source is non-zero and the input of this Node ID Source is low when 1353 power on, the Node ID Low parameter will be applied as the 1353 CAN Node ID. Must cycle power or send an NMT Reset for new value to take effect.
Store Parameters	RO	0x1010	0x00	0x01	Length of this object.
	RW		0x01	*4 bytes*	1353 supports only the mandatory Save All Parameters sub-index. See Table 2b for more details.
Restore Default Parameters	RO	0x1011	0x00	0x01	Length of this object.
	RW		0x01	*4 bytes*	Controls normal, factory, or backup restore. See Table 2c for more details.
Emergency COB ID	RO	0x1014	0x00	0x00000080 –0x000000FF	11-bit Identifier of the Emergency Message. Only the lowest 11 bits are valid. All other bits must be 0.
Emergency Rate	RW	0x1015	0x00	0 – 1000 ms *0 – 1000* in 4ms steps	Sets the minimum time that must elapse before another Emergency Message can be sent by the 1353. A setting of 0 disables the Emergency Message.
Heartbeat Rate	RW	0x1017	0x00	0 – 1000 ms *0 – 1000* in 4ms steps	Sets the cyclic repetition rate of the Heartbeat Message. A setting of 0 disables the Heartbeat.

Table 2 Communication Profile Object Dictionary cont'd

Name	Access	Index	Sub-index	Range *Can Value*	Description
Identity Object	RO	0x1018	0x00	0x06	Length of this structure = 6 sub-indexes.
	RO		0x01	0x00004349	Curtis ID as defined by CiA.
	RO		0x02	0x05490FA1 0x05491005 0x05491771 0x054917D5	Product code: 2 upper bytes = 1353 2 lower bytes = model number, −4001, −4101, −6001, or −6101.
	RO		0x03	*4 bytes*	Format is Major version in upper 2 bytes and Minor version in lower 2 bytes. The bytes are split upper byte for HW and lower byte for SW. Example: HW version 1.2 with SW version 3.4 = 0x01032040
	RO		0x04	0 – 999999	Serial Number up to 999,999.
	RO		0x05	1 – 99366	Date Code up to 99, Dec 31.
	RO		0x06	A – Z *0x41 – 0x5A*	ASCII code of the manufacturer's location.

Table 2 Column Definitions

Access: RO = Read Only access; RW = Read/Write access

Index: The CAN address that is used to access this object.

Sub-index: Some objects have several values associated with them. In these cases, a Sub-index is used to access each part of the object.

Detail on the Manufacturer's Status Registers, Store Parameters, and Restore Parameters objects is presented in Tables 2a, 2b, and 2c.

Manufacturer's Status Register

The Manufacturer's Status Register reflects the present fault flags. Each fault has its own bit in the Status Register. Unlike the LED Status of the Emergency Message, which can only relay the highest priority fault, the 32-bit Status Register 1 and Status Register 2 show **all** present faults. See Section 6: Diagnostics and Troubleshooting for descriptions and probable causes of the faults.

Table 2a Manufacturer's Status Registers

Status Register 1		Status Register 2	
Bit Location	**Fault**	**Bit Location**	**Fault**
LSB: Bit 0	Internal Fault	LSB: Bit 0	CANbus Fault
Bit 1	5V Supply Fail	Bit 1	Overcurrent
Bit 2	12V Supply Fail	Bit 2	Node ID Source Fault
Bit 3	External Supply Out of Range	Bits 3–31	[Reserved]
Bit 4	EEPROM Fault		
Bit 5	Analog Input Fault		
Bit 6	Encoder Fault		
Bit 7	Overvoltage		
Bit 8	Undervoltage		
Bit 9	Over-Temp		
Bit 10	Under-Temp		
Bit 11	Overcurrent		
Bits 12 – 20	Driver Fault (Bit 12 for Driver 1)		
Bits 21 – 29	Coil Fault (Bit 21 for Driver 1)		
Bit 30	PDO Timeout		
Bit 31	CANbus Fault		

Store Parameter Object

The Store Parameter Object controls when and if the changes made to the Object Dictionary (by SDO Write) are moved (stored) into EEPROM. An SDO read of the Save All Parameters sub-index 0x01 will return the present EEPROM Storage functionality. An SDO write to this sub-index is used to change the EEPROM Storage functionality. Note that the Save Type is always saved to EEPROM (even the No_Save option) so that the 1353 will power up in the desired mode.

The text strings "save" and "bkup" initiate a complete storage of all parameters to either the Normal EEPROM space or the Backup EEPROM space.

Table 2b Store Parameter Object

Function Request	Value	RW	Description
SET_NO_SAVE	0	RW	Device will not save parameter changes to EEPROM.
SET_SAVE_ON_COMMAND	1	RW	Device will save parameter changes to EEPROM on command.
SET_AUTO_SAVE	2	RW	Device will save parameter value to EEPROM automatically upon the SDO Write request.
SET_BOTH_SAVE	3	RW	Changes are saved on command and also automatically.
SAVE_COMMAND	"save" 0x65766173	RO	Text string that commands all parameters to be saved from working RAM to normal EEPROM space.
BACK_UP_COMMAND	"bkup" 0x70756B62	RO	Text string that commands all parameters to be saved from working RAM to the Backup EEPROM space. Not that this function works independent of the Save type setting (even No_Save).

At first glance, the ASCII looks "backward." This is because CANopen defines that the LSB goes first and MSB is sent last. Therefore "save" (which is data bytes 5, 6, 7, and 8) is written as "evas" when converting it to hex (data bytes in proper descending order). Using the ASCII hex values for each character, we get 65h ("e"), 76h ("v"), 61h ("a"), and 73h ("s") for the final resultant hex 6 byte number of 0x 65766173.

A text string is required (by DS301) for the SAVE_COMMAND to increase security. On reception of the correct string, the 1353 stores the parameters and then confirms the SDO transmission. If the storing failed, the 1353 responds with an Abort SDO. If a wrong string or unsupported command is written, the 1353 will not store and responds with an Abort SDO.

The "save" string will cause the 1353 to write all RW parameters from the Working RAM locations into the Normal EEPROM locations. The Normal EEPROM block is accessed during standard SDO write requests.

The "bkup" string will write into the secondary Backup EEPROM block. This block is not written to by normal SDO write requests and can only be accessed by the "load" command.

Note that of these six requests, only "save" is defined by DS301; the others are Curtis extensions.

Restore Default Parameters

The Restore Default Parameters Object allows the 1353 to restore all EEPROM backed-up SDO objects to their Factory (hard-coded in software), OEM (stored in a secondary/Backup EEPROM section), or Normal (stored in primary/Normal EEPROM section and accessed by standard SDO) settings. This object is also used to restore (reset) the hour meter value.

Writing a special text string to this sub-index will initiate a restore to Factory, Backup, or Normal settings for all EEPROM backed-up SDO objects. Once this object is written to, the next reset (by NMT or cycling power) will cause the system settings to load from the new desired EEPROM locations and put into the working RAM locations (Shadow RAM).

A Restore Defaults from Backup EEPROM command ("load") will load the data values from the Backup EEPROM, place them in RAM, and over-write the settings in the Normal EEPROM. Whatever changes were made to the Normal EEPROM will be lost. The Backup EEPROM Restore Default Parameter should be set to Restore Normal Defaults (0x02) so that the 1353 will restore from the Normal EEPROM on the next reset or power cycle.

Table 2c Restore Default Parameters Object

Restore Default Parameters Function	Write String	Data Read Back	Description
Restore Factory Defaults	"fact" 0x74636166	0	Restore all parameter values from built-in defaults. These are hard-coded in the software.
Restore the Back-Up Defaults	"load" 0x64616F6C	1	Restore all parameter values from the Backup EEPROM data bank. "load" is used to comply with CANopen spec DS301.
Restore User Defaults	"norm" 0x6D726F6E	2	Restore all parameter values from the Normal EEPROM data bank.
Preset the Hour Meter	"hour" 0x72756F68	N/A	Preset the hour meter to the value loaded into the parameter Preset Hour (0x3040).

On reception of the correct string, the 1353 updates the EEPROM and then confirms the SDO transmission. If the restore from FLASH into EEPROM failed, the 1353 responds with an Abort SDO. If a wrong string or unsupported command is written, the 1353 will not set the restore flag and responds with an Abort SDO.

A "fact" command will load the parameter values from the Factory section. To move these parameter values into the Normal EEPROM section, issue a "save" command to the Store Parameter Object and then cycle KSI.

The hour meter has a special function to reset it. Writing the string "hour" to this index will cause the 1353 to preset the hour meter to the value saved in the Preset Hour Meter parameter (0x3040). Note that only the hours can be set to a programmed value; the minutes always will be reset to 0.

PARAMETER PROFILE OBJECTS

The parameters found in the 0x3000 CAN Object address range are shown in Table 3. All these parameters have Read/Write (RW) SDO access, except for the sub-index 0x00 in a parameter array, which is Read Only (RO) as indicated.

Table 3 Parameter Profile Object Dictionary

Parameter	SDO Location		Range *Can Value*	Description
	Index	Sub-index		
Operation Mode	0x3000	0x01 – 0x09	0 – 3, 5 – 7 *0 – 3, 5 – 7*	Driver mode: 0 = Active High Digital Input mode. 1 = Constant Current mode. 2 = Constant Voltage mode. 3 = Direct PWM mode. 5 = Constant Current mode, with open detection. 6 = Constant Voltage mode, with open detection. 7 = Direct PWM mode, with open detection.
Max Current	0x3001	0x01 – 0x09	0.00 – 3.00 A *0 – 300*	Sets the maximum current output when the PDO command is 100% (255), **when operating in Constant Current mode.**
Min Current	0x30F4	0x01 – 0x09	0.00 – 3.00 A *0 – 300*	Sets the minimum current output when the PDO command is none-zero, **when operating in Constant Current mode.**
PWM Limit	0x3002	0x01 – 0x09	0 – 100.0 % *0 – 1000*	Sets the maximum PWM output when the PDO command is 100% (255), **when operating in Direct PWM mode.**
Voltage Limit	0x3003	0x01 – 0x09	0.0 – 36.0 V *0 – 360* (36V models) 0.0 – 80.0 V *0 – 800* (80V models)	Sets the maximum voltage output when the PDO command is 100% (255), **when operating in Constant Voltage mode.**
Dither Period	0x3004	0x01 – 0x09	4 – 200 ms *4 – 200*	Sets the time between dither pulses for each output (in 2 ms steps). A dither period of 4 – 200 ms provides a frequency range of 250 – 5 Hz. Applicable only in Constant Current mode.
Dither Amount	0x3005	0x01 – 0x09	0 – 500 mA *0 – 500*	Sets the amount (+/–) of dither that will be added/ subtracted from the command (in 10 mA steps). Applicable only in Constant Current mode.
Kp	0x3006	0x01 – 0x09	0.1 – 100.0 % *1 – 1000*	Sets the proportional gain factor of the PI current controller.
Ki	0x3007	0x01 – 0x09	0.1 – 100.0 % *1 – 1000*	Sets the integral gain factor of the PI current controller.
Ramp Up	0x30F5	0x01–0x09	1 – 1000ms *1 – 1000*	Set the time (in ms) to go from min to max current.
Ramp Down	0x30F6	0x01–0x09	1 – 1000ms *1 – 1000*	Set the time (in ms) to go from max to min current.
Nominal Voltage	0x3010	0x00	12.0V – 36.0 V *120 – 360* 36.0V – 80.0 V *360 – 800*	Sets the nominal battery voltage, which is used in fault detection. 1353–4101/4001: 12 V, 24V, 36V. 1353–6101/6001: 36 V, 48V, 60V, 72V, 80V.
Analog Input Type	0x3020	0x00	0 – 63 *0 – 63*	Sets the input type on Analog 1 through 6. LSB is for Analog 1 and next is for Analog 2, etc. Upper two bits are not used. Bit = 0, voltage input type. Bit = 1, resistive input type.

Table 3 Parameter Profile Object Dictionary, cont'd

Parameter	SDO Location		Range Can Value	Description
	Index	Sub-index		
High Threshold	0x3021	0x01 – 0x06	0.0 – 15.0 V *0 – 150*	Sets the threshold that the analog input must go above to set the virtual digital input high.
Low Threshold	0x3022	0x01 – 0x06	0.0 – 15.0 V *0 – 150*	Sets the threshold that the analog input must go below to set the virtual digital input low.
Filter Gain	0x3023	0x01 – 0x06	128 s – 8 ms *1 – 16384*	Sets the amount of filtering on the analog inputs. Higher gains provide faster filtering. Filtering affects the analog reading and the virtual digital input responsiveness.

Analog Fault Enable	0x3072	0x00	0 – 63	Bit variable to enable (set to 1)/disable (set to 0) analog fault detection.
				    bit0: analog1
				    bit1: analog2
				    . . .
				    bit5: analog6

Debounce Time	0x3024	0x01 – 0x09	8 – 1000 ms *8 – 1000*	Sets the debounce time of the digital inputs in milliseconds (in 8 ms steps)

Baud Rate	0x3030	0x00	−2 – 4 *−2 – 4*	Sets the CAN baud rate:
				    −2 = 50 kbit/s.
				    −1 = 100 kbit/s.
				    0 = 125 kbit/s.
				    1 = 250 kbit/s.
				    2 = 500 kbit/s.
				    3 = 800 kbit/s.
				    4 = 1Mbit/s.
				Resets to 125 kbit/s when over-range. Must cycle KSI for new rate to take effect.

PDO Timeout	0x3031	0x00	0 – 1000 ms *0 – 1000*	Sets the time interval (in 4 ms steps) within which the PDO MOSI must be received or a fault will be flagged. A setting of zero disables the PDO timeout fault.
Preset Hour	0x3040	0x00	0 – 65535 h *0 – 65535*	Writing to this location will change the hours of hour meter and reset the minutes to 0.

Encoder Type	0x3050	0x01 – 0x02	0 – 4 *0 – 4*	Encoder type:
				    0 = Encoder disabled.
				    1 = Pulse count type.
				    2 = RPM type.
				    3 = Position type.
				    4 = Analog 1 used for a single sine frequency input (not a quadrature input); this option is available only for Encoder 1.
				Must cycle KSI for new setting to take effect.

Encoder Direction	0x3051	0x01 – 0x02	0, 1 *0, 1*	Sets the positive direction:
				    0 = Positive direction when phase A is ahead of phase B.
				    1 = Positive direction when phase B is ahead of phase A.
				Must cycle KSI for new setting to take effect.

Pulses Per Meter	0x3052	0x01 – 0x02	0 – 65535 *0 – 65535*	This parameter should be set according to the pulses per revolution and displacement per revolution of the encoder. $$\text{Pulses Per Meter} = \frac{\text{pulses per revolution}}{\text{displacement per revolution (unit m)}}$$

Table 3 Parameter Profile Object Dictionary, cont'd

Parameter	SDO Location		Range *Can Value*	Description
	Index	Sub-index		
Pulse Per Revolution	0x3053	0x01 – 0x02	0 – 65535 *0 – 65535*	This parameter should be set according to the encoder specification. Must cycle KSI for new setting to take effect.
Encoder Reset	0x3054	0x01 – 0x02	0, 1 *0, 1*	Writing 1 to this index will immediately set the encoder counter to zero.
Min RPM	0x30F7	0x01 – 0x02	*0 – 65535*	The min RPM value to start encoder fault check. Set to 0 will disable encoder fault check.
Serial Port Enable	0x3060	0x00	0, 1 *0, 1*	1 = Serial port enabled (default for 1353-4101/6101) 0 = Serial port disabled (default for 1353-4001/6001). Note: the serial port can be used as Analog Inputs 5&6 once disabled.
Node ID High	0x3070	0x00	*1 – 127*	If selected Node ID Source is non-zero, and the input of this Node ID Source is high when 1353 power on, the Node ID High parameter will be applied as 1353 CAN Node ID Must cycle power or send an NMT Reset for new value to take effect
Node ID Source	0x3071	0x00	*0 – 15*	Select CAN Node ID source input. 0: No source input 1–9: Digital input1– 9 is used as the Node ID source 10–15: Virtual digital input1–6 is used as the Node ID source Must cycle power or send an NMT Reset for new value to take effect

Note: Parameter arrays have a sub-index 0x00 that is Read Only and returns the length of the array. This is not true of calibrations. This sub-index was added to be DS301 compliant, and the calibrations are Curtis proprietary and were not changed to be compatible with the ATS software.

Scaling:

10.3 volts = 103

3.01 amps = 301

240 ohms = 240

10.5% = 105

25 ms = 25 (DS301 defines short time periods to be in ms)

65000 hours = 65000

Application EEPROM Space

1353 provides 40 EEPROM spaces (32-bit) to store miscellaneous data for application use. These spaces can be accessed by SDO command as follows.

NAME	R/W	INDEX	SUB-INDEX	RANGE CAN VALUE	DESCRIPTION
Data 1	RW	0x3400	0	32bit	EEPROM spaces which can be used to store miscellaneous data
Data 2		0x3401			
Data 3		0x3402			
Data 4		0x3403			
Data 5		0x3404			
Data 6		0x3405			
…..		….			
…..		….			
Data 39		0x3426			
Data 40		0x3427			

Driver Proportional Gain / Driver Integral Gain

The 1353 uses a Proportional/Integral (PI) controller to minimize the error between the command and the actual output in Constant Current mode and Constant Voltage mode. The PI controller works with two parameters, proportional gain (Kp) and integral gain (Ki). Normally, the default settings of these gains are sufficient to control the load. However, there may be times when they need to be adjusted to increase or decrease the responsiveness of the 1353.

If the 1353 over-reacts to changes in battery or load, lower these gains. If it is too slow to react, increase them. If the gains are set too high, the output may oscillate. Normally, the Proportional and Integral gains are increased or decreased together. It is not recommended to have one gain very high while the other is very low.

Analog Input Algorithms

The voltage range of the six analog inputs is 0–15V and is scaled as 0–4095. The analog inputs are sampled after the nine driver output currents have been sampled. Each analog input is filtered by a single pole exponential filter. The Filter Gain parameter is associated with the Timer Constant (TC) of the filter, which indicates how long it takes the filter to respond to a step input and reach 63% of the final value. It takes approximately 5 TCs before the filtered signal reaches its full output. The table below provides a way to estimate filter response.
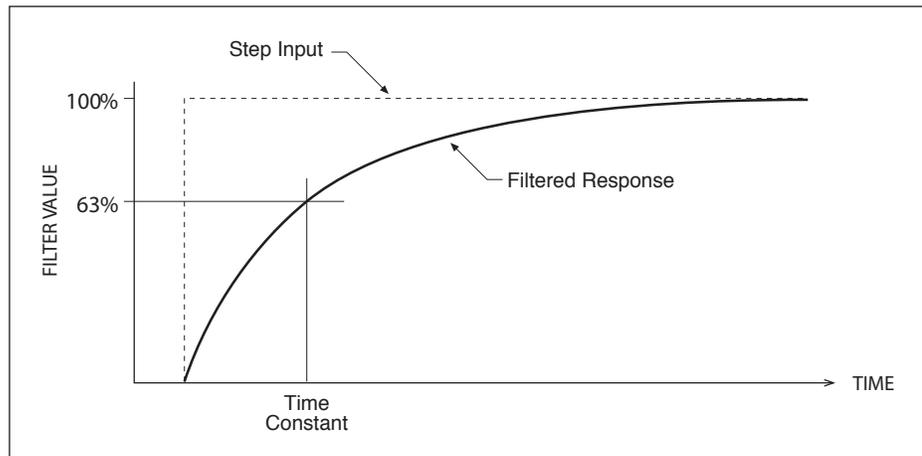
Exponential Filter Response

Setting	TC	Time to 100%
1	64 s	320 s
2	32 s	160 s
4	16 s	80 s
8	8 s	40 s
16	4 s	20 s
32	2 s	10 s
64	1 s	5 s
128	512 ms	2.5 s
256	256 ms	1.25 s
512	128 ms	640 ms
1024	64 ms	320 ms
2048	32 ms	160 ms
4096	16 ms	80 ms
8192	8 ms	40 ms
16384	4 ms	20 ms

The analog input can be configured as voltage input type or as resistive input type. The value measured at the six analog inputs is placed in the two MISO PDOs as filtered voltage (in units of 0.01 V) or resistance (in units of ohms), depending on the input type.

MONITOR OBJECTS

The following monitor objects are found in the 0x3100 CAN Object address range, as shown in Table 4.

Table 4 Monitor Object Dictionary

Parameter	SDO Location		Range *Can Value*	Description
	Index	Sub-index		
Analog 1 Resistor Value	0x3100	0x01	0 – 7500 Ω *0 – 7500*	Resistive type analog input value. The scale is returned as 1 ohm per count.
Analog2 Resistor Value		0x02		
Analog 3 Resistor Value		0x03		
Analog 4 Resistor Value		0x04		
Analog 5 Resistor Value		0x05		
Analog 6 Resistor Value		0x06		
Analog 1 Voltage Value	0x3101	0x01	0.00 – 15.60 V *0 – 1560*	Voltage type analog input value. The scale is returned as 0.01 volt per count.
Analog 2 Voltage Value		0x02		
Analog 3 Voltage Value		0x03		
Analog 4 Voltage Value		0x04		
Analog 5 Voltage Value		0x05		
Analog 6 Voltage Value		0x06		
Heatsink Temperature	0x3110	0x00	−40.0 +100.0°C *−400 – 1000*	Internal temperature of the 1353.
Battery Voltage	0x3120	0x00	0.0 – 120.0 V *0 – 1200*	Battery voltage as read by the 1353.
Driver 1 Current	0x3130	0x01	0.00 – 3.00 A *0 – 300*	Present current sunk by the driver.
Driver 2 Current		0x02		
Driver 3 Current		0x03		
Driver 4 Current		0x04		
Driver 5 Current		0x05		
Driver 6 Current		0x06		
Driver 7 Current		0x07		
Driver 8 Current		0x08		
Driver 9 Current		0x09		
Driver 1 PWM	0x3131	0x01	0.0 – 100.0% *0 – 1000*	Present PWM % of the driver.
Driver 2 PWM		0x02		
Driver 3 PWM		0x03		
Driver 4 PWM		0x04		
Driver 5 PWM		0x05		
Driver 6 PWM		0x06		
Driver 7 PWM		0x07		
Driver 8 PWM		0x08		
Driver 9 PWM		0x09		

Table 4 Monitor Object Dictionary, cont'd

Parameter	SDO Location		Range *Can Value*	Description
	Index	Sub-index		
Total Current of Drivers	0x3150	0x00	0.00 – 18.00 A *0 – 1800*	Total current of all 9 drivers.
Switch Input Status	0x3160	0x00	0 – 0x1FF *0 – 0x1FF*	Status of switch inputs 1: High, 0:Low
Virtual Digital Input Status	0x3170	0x00	0 – 0x3F *0 – 0x3F*	Status of virtual digital inputs: 1: High, 0:Low
5 V Voltage	0x3180	0x00	0.0 – 6.3 V *0 – 63*	Voltage value of the +5 V output.
12 V Voltage	0x3190	0x00	0.0 – 16.0 V *0 – 160*	Voltage value of the +12 V output.
Ext Current	0x31A0	0x00	0 – 250 mA *0 – 250*	Total current on +5 V and +12 V outputs.
Encoder 1 Count	0x31B0	0x00	$-2^{29} - 2^{29}-1$ *$-2^{29} - 2^{29}-1$*	Current Encoder 1 pulse count. Negative count means the encoder is running in the reverse direction of the zero position.
Encoder 2 Count		0x01		Current Encoder 2 pulse count. Negative count means the encoder is running in the reverse direction of the zero position.
Encoder 1 RPM	0x31C0	0x00	0 – 65535 rpm *0 – 65535*	Encoder 1 RPM in revolutions per minute when Encoder 1 is configured as RPM type.
Encoder 2 RPM		0x01		Encoder 2 RPM in revolutions per minute when Encoder 2 is configured as RPM type.
Encoder 1 Position	0x31d0	0x00	–32.768 – 32.767 m *–32768 – 32767*	Calculated position 1 value according to the pulse per meter when Encoder 1 is configured as Position type.
Encoder 2 Position		0x01		Calculated position 2 value according to the pulse per meter when Encoder 2 is configured as Position type.

6 — DIAGNOSTICS AND TROUBLESHOOTING

When an error occurs in the 1353, a fault message can be monitored through the Curtis programmer. Meanwhile, an emergency message will be produced on the CANbus according to the CANopen standard. This message will be sent once. When the fault clears, a No Fault emergency message will be transmitted.

For each new fault, the fault code and timestamp will be logged in a 16-error-deep FIFO buffer in this format:

Byte5	Byte6	Byte7	Byte8
Fault Code	FFh	Hour LSB	Hour MSB
Fault		Time Stamp	

The fault log is accessed by SDO reads of the Standard Object at Index 0x1003. Reading the Fault Log Length sub-index 00h will return a value of 16 (the depth of the fault log). Reading from the sub-index 1 though 16 (0x01 – 0x10) will return the faults plus time stamps in order from newest to oldest. The fault log can be cleared by writing 0 to the Fault Log Length object (sub-index 0x00).

Additionally, the highest priority fault code will be flashed on the red and yellow status LEDs. The red LED enumerates the digit place and the yellow LED enumerates 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. The 1353's two LEDs will display this repeating pattern:

Red	Yellow	Red	Yellow
✳	✳ ✳	✳ ✳	✳ ✳ ✳
(first digit)	(2)	(second digit)	(3)

The fault codes are listed in the troubleshooting chart (Table 5).

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 5 Troubleshooting Chart

Code	Fault	Description	Effect	Recovery
Fast Red LED	Corrupt Code	1353 in corrupted state.	1353 in Fault state.	Requires repair or new software download.
11	Internal Fault	Encryption failure.	1353 in Stopped state.	Requires repair and ATS test.
12	EEPROM Fault	EEPROM did not properly write, or Checksum did not match.	All outputs stopped.	Write to failed location.
13	5 V Supply Fail	External load impedance on +5 V Supply is too low.	None.	Bring voltage within range.
14	12 V Supply Fail	External load impedance on +12 V Supply is too low.	None.	Bring voltage within range.
15	External Supply Out of Range	External load on +5 V or +12 V exceeds 200 mA.	None.	Bring external supply current within range.
16	Flash Fault	The flash did not properly write.	1353 in Stopped state.	Write to failed location.
17	Analog Input Fault	Analog input exceeds 15.5 V(voltage input) or 7.5 K(resistance input).	None.	Bring analog input within range.
18	Encoder Fault	Encoder wire open.	Encoder count stopped.	Cycle KSI.
21	Overvoltage	Battery over limit. Limit = (Nominal Voltage * 1.25) + 5 V.	All outputs stopped.	Battery returns to normal range for >1 second.
22	Undervoltage	Battery under limit. Limit = 8.5V for 1353–4xxx Limit = 15.5V for 1353–6xxx	All outputs stopped.	Battery returns to normal range for >1 second.
23	Overtemp	Heatsink over allowed temperature	All outputs stopped.	Temp returns to normal range (<95°C).
24	Undertemp	Heatsink below allowed.	All outputs stopped.	Temp returns to normal range (>−50°C).
25	Overcurrent	Total current exceeds 18A.	All outputs stopped.	Total current returns to normal range (≤18A).
31	Driver1 Fault	Driver is in overcurrent (>3.5 amps)	Output on the faulted driver stopped.	Send a 0% PDO command to the faulted driver.
32	Driver2 Fault			
33	Driver3 Fault			
34	Driver4 Fault			
35	Driver5 Fault			
36	Driver6 Fault			
37	Driver7 Fault			
38	Driver8 Fault			
39	Driver9 Fault			

Table 5 Troubleshooting Chart cont'd

Code	Fault	Description	Effect	Recovery
41	Coil1 Fault	Driver output pin is low when driver is Off. This implies the pin has been left open.	Output on the faulted driver not functional.	Driver pin is reconnected.
42	Coil2 Fault			
43	Coil3 Fault			
44	Coil4 Fault			
45	Coil5 Fault			
46	Coil6 Fault			
47	Coil7 Fault			
48	Coil8 Fault			
49	Coil9 Fault			
51	PDO Timeout	PDO from master has not been received within the time-out period.	All drivers disabled and commands cleared.	New PDO received within proper timing.
52	CANbus Fault	Too many CANbus errors detected.	1353 is offline.	No CANbus errors.
54	CAN Node ID Source Fault	Node ID Source is not set correctly.	Node ID Low parameter is applied to the CAN Node ID.	Correct Node ID Source input mode and Cycle KSI.

FAULT LOG

The 1353 stores the last 16 faults with a time-stamp. The Fault Log is stored in non-volatile memory with the last fault always at the top of the log and the oldest fault at the end. If the buffer is full when a new fault occurs, the oldest fault is pushed of the log, the previous faults all move down, and the newest fault is placed at the top.

The Fault Log is accessed by SDO reads of the Standard Object at Index 0x1003 (called the Pre-defined Error Field in DS301). Reading the Fault Log Length sub-index 0x00 will return a value of 16 (the depth of the fault log). Reading from the sub-index 1 though 16 (0x01 – 0x10) will return the faults plus time stamps in order from newest to oldest.

Faults are stored in the Fault Log as 32-bit data fields in this format:

	byte 5	byte 6	byte 7 & 8
	Fault Code	FFh	Hourmeter *
	Fault		Time Stamp

*Note that the MSB of the hourmeter is in Byte 8.

The first byte is the fault code; see Table 5. The next byte simply indicates a fault and is consistent with the Emergency Message. If the SDO read of a fault log sub-index returns a 0 in the fault data, the fault log is clear at that location, and no fault was recorded.

The time-stamp uses the internal 16-bit running hour meter. If several error messages have occurred within one hour, the order of the fault messages will indicate which came first.

The Fault Log can be cleared by writing 0 to the Fault Log Length object (sub-index 0x00). After clearing, all the data bytes in sub-indexes 0x01 through 0x10 will be 0.

7 — SERIAL COMMUNICATIONS & PROGRAMMING

The 1353 models with a serial port (1353–4101 and –6101) are compatible with Curtis programmers; see App. B. The Analog 5 and 6 inputs are multiplexed with Serial Tx and Rx. The serial port function is enabled via CANopen SDO. Once the serial port is enabled, it implements the ESP protocol and can support the Curtis handheld 1313 programmers and the 1314 PC programming station. The 1353's default serial baud rate is 9600bit/s.

The Curtis programmer can be used to adjust the programmable parameters, to read various monitored values, and to access fault information.

PROGRAM MENUS

The programmable parameters are arranged in hierarchical menus, as shown in Table 6.

Table 6 Program Menus: 1313/1314 Programmer

— Analog1
   — Input Type
   — High Threshold
   — Low Threshold
   — Filter Gain
   — Analog Fault
— Analog2 *(same)*
— Analog3 *(same)*
— Analog4 *(same)*
— Analog5 *(same)*
— Analog6 *(same)*

— Input1 Debounce Time
. . .
— Input9 Debounce Time

— Encoder1
   — Encoder Type
   — Pulse Per Meter
   — Pulse Per Revolution
   — Swap Direction
   — Reset
   — Fault
      — Min RPM
— Encoder2 *(same)*

— Driver1
   — Operation Mode
   — Output Limits
      — Current
         — Max
         — Min
      — Voltage
      — PWM
   — Dither
      — Period
      — Amount
   — PI
      — Kp
      — Ki
   — Ramp
      — Up
      — Down
— Driver2 *(same)*
. . .
— Driver9 *(same)*

— Baud Rate
— Node ID Source
— Node ID Low
— Node ID High
— Heartbeat Rate
— PDO Timeout
— Emergency Rate

— Nominal Voltage
— Preset Hour
— Restore Type

ANALOG INPUT PROGRAM MENU *

PARAMETER	ALLOWABLE RANGE	DESCRIPTION

Input Type	0, 1	Selects the analog type:
		   0 = Voltage type input.
		   1 = Resistive type input.

High Threshold	0.0 – 15.0 V	Sets the threshold the analog input must go above to set the virtual digital input High.
Low Threshold	0.0 – 15.0 V	Sets the threshold the analog input must go below to set the virtual digital input Low.
Filter Gain	1 – 16384	Sets the amount of filtering on the input. Higher gains provide faster filtering. Filtering affects the analog reading and the virtual digital input responsiveness.
Analog Fault	On / Off	On = Enable analog fault detection Off = Disable analog fault detection

* This menu is repeated for Analog Inputs 1 – 6.

DIGITAL INPUT PROGRAM MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input1 Debounce Time	8 – 1000 ms	Sets the debounce time of Digital Input 1 in 8 ms steps.
Input2 Debounce Time	8 – 1000 ms	Sets the debounce time of Digital Input 2 in 8 ms steps.
. . .		
Input9 Debounce Time	8 – 1000 ms	Sets the debounce time of Digital Input 9 in 8 ms steps.

ENCODER PROGRAM MENU *

PARAMETER	ALLOWABLE RANGE	DESCRIPTION

Encoder Type	0 – 4	Selects the encoder type:
		   0 = Encoder disabled.
		   1 = Pulse count type.
		   2 = RPM type.
		   3 = Position type.
		   4 = Analog 1 is used for a single sine frequency, not for a quadrature input.
		Must cycle KSI for new encoder type to take effect.
		Note: Type 4 is not available for Encoder 2.

Pulse Per Meter	0 – 65535	This parameter should be set according to the pulses per revolution and displacement per revolution of the encoder: $$Pulses\ Per\ Meter = \frac{pulses\ per\ revolution}{displacement\ per\ revolution\ (unit\ m)}$$
Pulse Per Revolution	0 – 65535	This parameter should be set according to the encoder specification. Must cycle KSI for new setting to take effect.

Swap Direction	0, 1	Sets the positive phase direction:
		   0 = Positive phase when phase A is ahead of phase B
		   1 = Positive phase when phase B is ahead of Phase A.
		Must cycle KSI for new setting to take effect.

Reset	0	Sets the encoder counter to zero.
Min RPM	0 – 65535	The min RPM value to start encoder fault check. Set to 0 will disable encoder fault detection.

* This menu is repeated for Encoders 1 and 2.

DRIVER OUTPUT PROGRAM MENU *

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Operation Mode	0 – 3, 5 – 7	Selects the driver operation mode: 0 = Active High Digital Input mode. 1 = Constant Current mode. 2 = Constant Voltage mode. 3 = Direct PWM mode. 5 = Constant Current mode (with open detection). 6 = Constant Voltage mode (with open detection). 7 = Direct PWM mode (with open detection).
Max Current	0.00 – 3.00 A	Sets the maximum current output when the PDO command is 100%; applicable only when the driver is operating in Constant Current mode.
Min Current	0.00 – 3.00 A	Set the minimum current output when the PDO command is none-zero; applicable only when the driver is operating in Constant Current mode
Voltage Limit	0.0 – 36.0 V *(36 V models)* 0.0 – 80.0 V *(80 V models)*	Sets the maximum voltage output when the PDO command is 100%; applicable only when the driver is operating in Constant Voltage mode.
PWM Limit	0.0 – 100.0 %	Sets the maximum PWM output when the driver is operating in Direct PWM mode.
Dither Period	4 – 200 ms	Sets the time between dither pulses (in 2 ms steps). A dither period of 4 – 200 ms provides a frequency range of 250 – 5 Hz.
Dither Amount	0 – 500 mA	Sets the amount (+/–) of dither that will be added/subtracted from the command (in 10 mA steps).
Kp	0.1 – 100.0 %	Sets the proportional gain factor of the PI current controller.
Ki	0.1 – 100.0 %	Sets the integral gain factor of the PI current controller.
Ramp Up	1 – 1000 ms	Set the time (in ms) to go from Min to Max current.
Ramp Down	1 – 1000 ms	Set the time (in ms) to go from Max to Min current.

* This menu is repeated for Drivers 1 – 9.

CAN INTERFACE PROGRAM MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Baud Rate	−2 – 4	Sets the CAN baud rate: −2 = 50 kbit/s. −1 = 100 kbit/s. 0 = 125 kbit/s. 1 = 250 kbit/s. 2 = 500 kbit/s. 3 = 800 kbit/s. 4 = 1 Mbit/s. Must cycle KSI **or** send an NMT RESET 1353 **or** send an NMT RESET CAN for the new baud rate to take effect.
Node ID Source	0 – 15	Select CAN Node ID source input. 0 = No source input 1–9 = Digital input1–9 is used as the Node ID Source 10–15 = Virtual digital input1–6 is used as the Node ID Source. Must cycle KSI or send an NMT Reset for new value to take effect.
Node ID Low	1 – 127	If Node ID Source is zero, or Node ID Source is none-zero and input value of source is low, then apply this parameter to be the CAN Node ID. Must cycle KSI or send an NMT Reset for new value to take effect.
Node ID High	1 – 127	If Node ID Source is none-zero and input value of source is high, then apply this parameter to be the CAN Node ID. Must cycle KSI or send an NMT Reset for new value to take effect.
Heartbeat Rate	0 – 1000 ms	Sets the cyclic repetition rate of the heartbeat message, in 4 ms steps. Setting this parameter to zero disables the heartbeat.
PDO Timeout	0 – 1000 ms	Sets the time interval, in 4 ms steps, within which the PDO-MOSI must be received. If the interval is longer than this set interval, a fault is flagged. Setting this parameter to zero disables the PDO timeout fault.
Emergency Rate	0 – 1000 ms	Sets the minimum time, in 4 ms steps, the time that must elapse before the 1353 can send another emergency message. Setting this parameter to zero disables the emergency message.

CONFIGURATION PROGRAM MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Nominal Voltage	1 – 7	Must be set to the vehicle's nominal battery pack voltage. This parameter is used in determining the overvoltage and undervoltage protection thresholds for 1353 1 = 12 V 2 = 24 V 36 V models 3 = 36 V 4 = 48 V 5 = 60 V 80 V models 6 = 72 V 7 = 80 V The Brownout Voltage is determined by the 1353 base type (1353-4xxx or 1353-6xxx) and cannot be changed. If the B+ voltage stays below the Brownout voltage for > 64 ms, the 1353 will reset (equivalent to cycling the KSI). If the B+ voltage rises above the Brownout voltage before 64 ms have passed, the 1353 will not reset.
Preset Hour	0 – 65535 h	Presets hours of the hour meter and resets the minutes to zero.
Restore Type	1, 2	This parameter is used to select the source of the parameters when the 1353 is powered on. 1 = Load parameters from back-up EEPROM block. 2 = Load parameters from normal EEPROM block. The default value for this parameter is 2. When it is programmed to 1, the 1353 will load all backup parameters after cycling KSI, and then the Restore Type value will reset to 2.

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 hierarchical menus, as shown in Table 7.

Table 7 Monitor Menus: 1313/1314 Programmer

ANALOG INPUT.............................. p. 46
— Analog1
— Voltage
— Resistance
— Virtual Digital
— Analog2 *(same)*
— Analog3 *(same)*
— Analog4 *(same)*
— Analog5 *(same)*
— Analog6 *(same)*

DIGITAL INPUT.............................. p. 46
— Input1
. . .
— Input9

ENCODER INPUT............................ p. 46
— Encoder1
— Pulse Counts
— RPM
— Position
— Encoder2 *(same)*

DRIVER OUTPUT............................ p. 46
— Driver1
— Current
— PWM
— Driver2 *(same)*
. . .
— Driver9 *(same)*
— Total Current

POWER SUPPLY OUTPUT............... p. 47
— 5V
— 12V
— EXT Current

TEMPERATURE............................. p. 47

BATTERY VOLTAGE........................ p. 47

HOUR METER............................... p. 47
— Hours
— Minutes

ANALOG INPUT MONITOR MENU *

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Voltage	0.0 – 15.6V	For modules that are configured as **voltage** input type, this variable displays the input voltage value.
Resistance	0 – 7500 Ω	For modules that are configured as **resistive** input type, this variable displays the input resistance value.
Virtual Digital	On / Off	Virtual digital input state.

* This menu is repeated for Analog Inputs 1 – 6.

DIGITAL INPUT MONITOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Input1	On / Off	Input state of Digital Input 1.
Input2	On / Off	Input state of Digital Input 2
. . .		
Input9	On / Off	Input state of Digital Input 9

ENCODER MONITOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Pulse Counts	$-2^{29} - 2^{29} - 1$	Current encoder pulse counts. Negative counts indicate the encoder is running in the reverse direction of the zero position.
RPM	0 – 65535 rpm	Displays RPM, when the encoder type is configured as RPM mode.
Position	−32.768 – 32.767 m	Displays position, when the encoder type is configured as position mode. Negative counts indicate the encoder is running in the reverse direction of the zero position.

DRIVER OUTPUT MONITOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Driver1 Current	0.00 – 3.00 A	Current sunk by Driver 1.
Driver1 PWM	0.0 – 100.0 %	PWM % of Driver 1.
. . .		
Driver9 Current	0.00 – 3.00 A	Current sunk by Driver 9.
Driver9 PWM	0.0 – 100.0 %	PWM % of Driver 9.
Total Current	0.00 – 18.00 A	Total current of all nine drivers.

POWER SUPPLY MONITOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Power Supply Output: +5 V	0.0 – 6.3 V	Voltage of the +5 V output.
Power Supply Output: +12 V	0.0 – 16.0 V	Voltage of the +12 V output.
Power Supply Output: EXT Current	0 – 250 mA	Combined current of the external +12 V and +5 V power supplies.

TEMPERATURE MONITOR PARAMETER

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Temperature	−40.0 – 100.0 °C	Internal temperature of the 1353.

BATTERY VOLTAGE MONITOR PARAMETER

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Battery Voltage	0.0 – 120.0 V	Voltage of the battery.

HOUR METER MONITOR MENU

PARAMETER	ALLOWABLE RANGE	DESCRIPTION
Hour Meter: Hours	0 – 65535 h	Present hours of the hour meter. The hourmeter runs all the time the 1353 is powered on.
Hour Meter: Minutes	0 – 59 min	Present minutes of the hour meter.

FAULT MENU

The Curtis programmer provides a convenient way to access fault information; see Section 6: Faults and Diagnostics. The programmer displays the faults by name. It displays all faults that are currently set and also a history of all the faults that have been set since the history log was last cleared.

APPENDIX A

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 motor controllers.

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 1353 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 1353 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 1353 models that have a serial port. 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 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 1313 handheld programmer is functionally equivalent to the PC Programming Station; operating instructions are provided in the 1313 manual. This programmer replaces the 1311, an earlier model with fewer functions.

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: 1353 MODULE

Nominal input voltage:	12 – 36 V, 36 – 80 V
Electrical isolation to heatsink:	500 V ac (minimum)
Storage ambient temperature range:	–40°C to 85°C (–40°F to 185°F)
Operating ambient temperature range:	–40°C to 50°C (–40°F to 122°F)
Enclosure protection rating:	IP65
Weight:	0.4 kg (0.3 lbs)
Dimensions (L×W×H):	130 × 100 × 39 mm (5.2" × 3.9" × 1.5") 87 mm (3.4") between mounting holes 6.3 mm (0.25") mounting hole ID
EMC:	Designed to the requirements of EN 12895: 2000.
Safety:	Designed to the requirements of EN 1175-1:1998+A1: 2010 and EN 13849-1: 2008 Category 2.
UL:	UL recognized component per UL583.

MODEl NUMBER	NOMINAL VOLTAGE	MINIMUM VOLTAGE	MAXIMUM VOLTAGE	BROWNOUT VOLTAGE	DESCRIPTION
1353-4001	12–36 V	8.5 V	50 V	7 V	Six analog inputs; no serial port
1353-4101	12–36 V	8.5 V	50 V	7 V	Four analog inputs and a serial port
1353-6001	36–80 V	15.5 V	105 V	13 V	Six analog inputs; no serial port
1353-6101	36–80 V	15.5 V	105 V	13 V	Four analog inputs and a serial port