

# SCOTT DRIVE



## Installation Manual

## SD100 and SD200

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# 1 Introduction

The Scott Drive 100 and Scott Drive 200 are Three Phase AC Motor Controllers which can be used to control either Brushless Permanent Magnet motors or AC Induction motors. It is targeted for use on electric vehicles and includes many features to simplify the conversion process and reduce the overall cost.

The Scott Drive line uses only the highest quality components carefully chosen for absolute durability. The IGBT's are Semikron SKiM modules which are sintered, not soldered, to greatly increase durability in extreme temperature cycles (-40C to +125C) and high vibration environments (shock rated to 50g). Integrated temperature sensing automatically prevents IGBT thermal damage. These are considered by many to be the finest in the world for electric vehicle applications.

## 1.1 Features

- SD100: 100 kW nominal output power (180 kVA peak input)
- SD200: 200 kW nominal output power (270 kVA peak input)
- Integrated Pre-Charge Circuit
- Integrated LEV200 Contactor
- External Coolant / Motor Temperature Monitoring
- Internal monitoring of IGBT temperature.
- Four 12V (10A) DC Motor Outputs
- Supports Encoder (QEP) or Hall Effect Sensor feedback from Motor
- Nine Digital Switch Inputs
- Regenerative Braking
- Liquid Cooling
- Integrated TCP/IP Ethernet, RS485 and CAN communications ports
- Drive setup can be configured via Ethernet port
- Firmware upgradeable via Ethernet port
- Heavy-Duty industrial waterproof connectors (IP67)

## **2 Warning – Electricity can be dangerous**

All AC and DC connections and cables above 48V should be considered potentially lethal. Only qualified individuals suitably trained and experienced with high voltages should be permitted to connect, disconnect, install, modify, or touch high-power wiring or connections.

### **2.1 Safety First!**

Always take full precautions when dealing with electricity and utilize all necessary personal protective equipment. This may include, but is not limited to:

- High-Voltage protective gloves
- Safety Goggles.
- Non-conductive and non-flammable protective clothing.
- Non-conductive footwear.
- Non-conductive tool handles and/or covers.

Always disconnect the input power source (example: battery pack) to the greatest extent possible before connecting, disconnecting, installing, modifying, or touching the high-power wiring or connections on the electric drive system.

- Always verify the power has been successfully disconnected (and is guaranteed to remain disconnected) using appropriate metering equipment **BEFORE** performing any actions to the electric drive.

Scott Drive LLC. and Scott Drive distributors/dealers are not liable for the use, misuse, or inability to use Scott Drive products or related hardware. It is your responsibility to take proper precautions deemed necessary and prudent by industry professionals when constructing, operating, maintaining, and modifying electric drive systems.

## **3 Mechanical Installation**

### **3.1 Mounting Position**

When determining the mounting position of the SD100 the following factors should be considered:

- Proximity: The SD100 should be mounted in close proximity to the motor to minimize the length of the motor power cables. Mounting the SD100 above the motor generally works well. This will also minimize the length of the water cooling tubing if it is shared with the motor.
- Clearance: While most of the electrical connections to the SD100 are at one end of the controller the motor cables and water cooling connections are located on separate sides of the controller. The clearance and minimum bending radius of all cables and tubing must be followed.
- Environment: While the SD100 is designed to be splash-proof it should be mounted in a position where it is protected from heavy rain and road dust. Please remember electricity and water don't mix!!!

### **3.2 Mechanical Mounting**

It is recommended that the SD100/SD200 be mounted using rubber isolation mounts. The controller should be restrained using the four 8mm tapped holes on the bottom side of the controller. The mounting surface should be quite sturdy in order to support the Scott Drive without flex or vibration on rough roads.

## 4 Electrical Installation

### 4.1 12V Supply Connection

The 12V supply to the Drive is via a 50A Anderson connector. The nominal current required for operation is 2 Amps to power the Digital and Analogue circuits and also the LEV200 contactor. If any of the 4 Auxiliary channels are used then the 12V supply current will be higher. The drive is designed to operate in the voltage range of 11-16V. The controller is grounded internally, so the unit does not need an external ground to the chassis.

### 4.2 High Power Connections

The DC Power is provided to the Drive controller via flying leads which can be terminated with crimp lugs or an Anderson connector. The length of the cable can be specified. Please see ordering options for more information.

The AC Power connections to the motor are provided via 10mm studs. It is highly recommended to use 35mm (AWG 2) or larger cable for the Scott Drive 100 and to keep the motor leads as short as possible to avoid EMI problems. Please note that larger cables and connectors provide lower resistance and greater heat-sink capability for high-power applications. For the Scott Drive 200 it is recommended to use 50mm (AWG 1/0) or larger.

**Warning! The high voltage lines must be isolated and never grounded. It is best practice to use protective conduit or similar means to ensure that high voltage wires cannot be chaffed and damaged from vibration, sharp edges, or exposure to the elements. It is recommended that a fuse of the appropriate rating be included into the battery circuit.**

### 4.3 Driver Control Inputs

An EPIC H-DD24 connector is provided for all Analog and Digital control inputs. This

ensures protection from both dirt and EMI using the shield connection. For maximum protection it is recommended to use shielded cabling between the Drive and all sensors, switches and pots. Depending on your hardware configuration not all inputs will be needed. The minimum set of required inputs includes the DRIVE MODE, FORWARD, REVERSE and E-STOP switch and the THROTTLE POT. In addition the Contactor In/Out connections must be connected. All the digital inputs are internally tied low inside the Scott Drive controller and should only be connected to the supplied +5V switch supply (Pin 1) to activate the pin functionality.

#### 4.3.1 Forward / Reverse Braking Inputs

The Forward and Reverse Brake inputs are active high and should not be active simultaneously.

#### 4.3.2 Drive Mode (KSI)

The Drive Mode input is active high and changes the internal mode of the Scott Drive controller. It is recommended to connect this input to a dedicated illuminated push button fitted in the dash rather than the key switch. When activated the internal mode of the controller changes from **Drive Standby** to **Drive Active** mode.

NOTE: There are two conditions that will stop the controller entering the Drive Active mode. The first condition is when the E-Stop input is open (E-Stop button activated). The second condition is when the Throttle level is positive. The resting throttle level should be adjusted to between -5 and -2% when not using the throttle to determine the regenerative braking level. If the throttle pot is used

#### 4.3.1 Interlock (CFO)

The Interlock (Charge Flap Open) input is tied low internally and must be connected high (+5V) for the drive to operate. This input can be connected to a micro switch on the charging flap/latch to automatically disable the drive when the car is being charged.

Pin Number	Function	Color Code
1	+5V SWITCH SUPPLY	White
2	REVERSE	Brown
3	BRAKE SWITCH	Green
4	FORWARD	Yellow
5	DRIVE MODE (KSI)	Grey
6	INTERLOCK (CFO)	Pink
7	EMERGENCY STOP	Blue
8	SPORT MODE	Red
9	REGEN DISABLE	Black
10	THROTTLE SWITCH	Violet
11	+5V THROTTLE POT SUPPLY	Grey/Pink
12	THROTTLE WIPER	Red/Blue
13	0V POT COMMON	White/Green
14	+5V BRAKE POT SUPPLY	Brown/Green
15	BRAKE WIPER	White/Yellow
16	0V POT COMMON	Yellow/Brown
17	+5V SENSOR SUPPLY	White/Grey
18	SENSOR INPUT	Grey/Brown
19	0V SENSOR SUPPLY	White/Pink
20	QEP I / Spare	Pink/Brown
21	QEP A / Spare	White/Blue
22	QEP B / Spare	Brown/Blue
23	CONTACTOR IN	White/Red
24	CONTACTOR OUT	Brown/Red
PE	SHIELD	

Table 4.1 Driver Control Connections

### 4.3.2 Emergency Stop

The Emergency Stop input is tied low internally and must be connected high (+5V)

for the drive to operate. For failsafe operation the input should be connected to the Normally Closed (NC) contacts when the Emergency Stop button is not active. When the Emergency Stop input is opened the Scott Drive controller will turn off all the IGBT switches and disable all drive operation until the Emergency Stop input is again closed.

In addition to the digital Emergency Stop input the Scott Drive controller also provides access to the internal Kilovac solenoid leads (Pin 23 & Pin 24). These pins **MUST be connected together** to enable the software to close the main contactor after the DC Link pre-charging is complete. These pins may either be connected together permanently or may be connected to a second pair of Normally Closed (NC) contacts in your Emergency Stop button. The reason for direct access to the Contactor Coil leads is to comply with regulations in some countries that specifies manual access to a direct mechanical or electromechanically disconnect option. The disadvantage of using the contactor to break the high voltage current is wear and tear on the contacts as the high voltage/high current arc dissipates under load.

Consequently Scott Drive provides the digital software sensed input as the primary Emergency stop method. The reaction time of the software to disable IGBT switching is less than 1ms. At the same time the Contactor solenoid coil supply is also disconnected by the software allowing the contacts to Open. As the typical KiloVac contact release time is 12ms the current draw should already be close to zero by the time the contacts open.

### 4.3.3 Sport Mode

The Sport Mode input can be used to change to a second pre-defined Throttle Mapping sensitivity. The input should be connected high to activate the Sport Mode. See section 7.1.4 on how to set the Sport Mode Throttle sensitivity using the SEV View software.

### 4.3.4 Regenerative Brake Disable

The Regenerative Brake Disable functions as an override to easily disable regenerative braking when road conditions become dangerous due to ice, rain or any other reasons.

## 4.4 Auxiliary Motor Outputs

Four auxiliary 12V/10A outputs are provided through an eight pin EPIC HD8 style connector. These outputs can be used to control low power DC motors (up to ~120W) such as water pump or vacuum pump motors. The ON state of the outputs can be set to coincide with a number of drive controller states, most commonly to activate when the drive enters the Active mode. The Low side return is switched to 0V via mosfets to activate the output. It is possible to PWM modulate the outputs if required.

Pin Number	Function
1	Channel One Return
2	Channel One +12V
3	Channel Two Return
4	Channel Two +12V
5	Channel Three Return
6	Channel Three +12V
7	Channel Four Return
8	Channel Four +12V

Table 4.2 Auxiliary Connector Pin Assignments.

## 4.5 Communication Interfaces

### 4.5.1 Ethernet TCP/IP

A standard RJ45 Ethernet connection is provided for easy connection to any PC. The Ethernet port is AUTO-MDIX enabled meaning it can be connected directly to either a PC or network switch without using a cross-over cable. PC based application software is provided which can be used for initial setup, in-field firmware upgrade or to simply view to operating parameters of the Drive.

### 4.5.2 CAN Bus

The CAN Bus port is provided primarily so the Drive controller can communicate with other Scott EV products such as the Battery Management System (BMS) and

charging system.

### 4.5.3 RS485

The RS45 port is included for future expandability and custom interfaces if requested. Please contact your local distributor if you wish to customize setup, control or diagnostic functions via RS485.

## 5 Liquid Cooling System

Your Scott Drive controller is equipped with liquid cooling ports for efficient cooling under high-power conditions. The minimum recommended flow is 3 liters/minute (.8 gal/min) on the SD100 and 5 liters/minute (1.5 gal/min) on the SD200. The use of distilled water and an antifreeze additive is required. This not only prevents freezing in low temperatures, but also helps to prevent scale and rust build-up which reduce heat transfer.

If the controller is mounted vertically (such as on the fire-wall of a vehicle), the coolant ports must not be facing down. This could lead to an air bubble in the chill plate and inadequate heat removal. If the controller is oriented so that one coolant port is above the other, then cool liquid should enter the lower port and warm fluid should exit the upper port (radiators and coolant reservoirs are the opposite, the warm fluid enters the top and cool fluid exits the bottom). It is strongly recommended the pump be the lowest part of the system and located both below and close to the radiator or reservoir. This will prevent difficult priming due to an air pocket.

For longest life and highest performance the controller should have its own coolant system to prevent motor heat from affecting the controller. This is especially important in racing or other extreme high-power applications. If the controller is placed in the same coolant loop as a motor, the controller should be located before the motor in the coolant loop. This can be done for expediency in moderate power applications. Coolant temperature should be kept under 40 C (104 F) for maximum performance.

Coolant system flow and radiator sizing requirements can vary quite a bit in different vehicles. Variables such as vehicle weight, system voltage, motor model, driving habits, terrain, speed, air-flow, ambient temperature, tubing size, fan, etc., all affect the cooling system performance. It is important to consider these factors when choosing components or designing the system. In general, it is wiser to error on the side of too much cooling rather than too little.

The Scott Drive controller is made with the highest quality components and will automatically reduce power output in order to keep from overheating. However, it is

always beneficial to keep electronic equipment as cool as possible to increase both power output and longevity. It is best practice to monitor the temperature of the coolant system by using a temperature sensor which is accurate below 100 F (35C). Do not use standard automotive temperature switches which only activate above 180 F (65 C). The chart below shows the benefit of keeping the controller as cool as possible.

### 5.1 IGBT Rated Output at Various Temperatures

Temperature	SD100 IGBT Rated Output	SD200 IGBT Rated Output	SD300 IGBT Rated Output
25 C (77 F)	468 A	641 A	899 A
40 C (104 F)	430 A	600 A	830 A
50 C (140 F)	400 A	575 A	800 A
70 C (158 F)	374 A	512 A	715 A
100 C (212 F)	300 A	410 A	575 A

## 6 Drive Configuration

The Scott Drive Controller can be configured using the SEV View application software via a standard Ethernet port. The following section details how to setup your PC or Laptop so it can communicate with the Scott Drive Controller.

### 6.1 Ethernet Communication Setup

To communicate with the Scott Drive Controller your PC must be setup to use a compatible IP address. The TCP/IP settings can be adjusted from the **Internet Protocol (TCP/IP) Properties** window.

When using XP this window can be accessed as follows. From the **Control Panel** open up the Network Settings window and right click on your **Local Area Connection** icon and select **Properties**. Select the **Internet Protocol (TCP/IP)** from the list of available connections and click on the Properties button. This will bring up the window in Figure 6.1.

The default IP address of all Scott Drive controllers is 10.1.1.100 when it leaves the factory. Consequently you should set the IP address of the PC to 10.1.1.x where x can be any number from 1 to 255 (except 100) and the subnet mask to 255.255.255.0.

The DNS addresses do not affect communication with the SD100. In the example above the PC address has been set to 10.1.1.5. Click **OK** when you are done. You may need to reboot your PC for the settings to be updated.

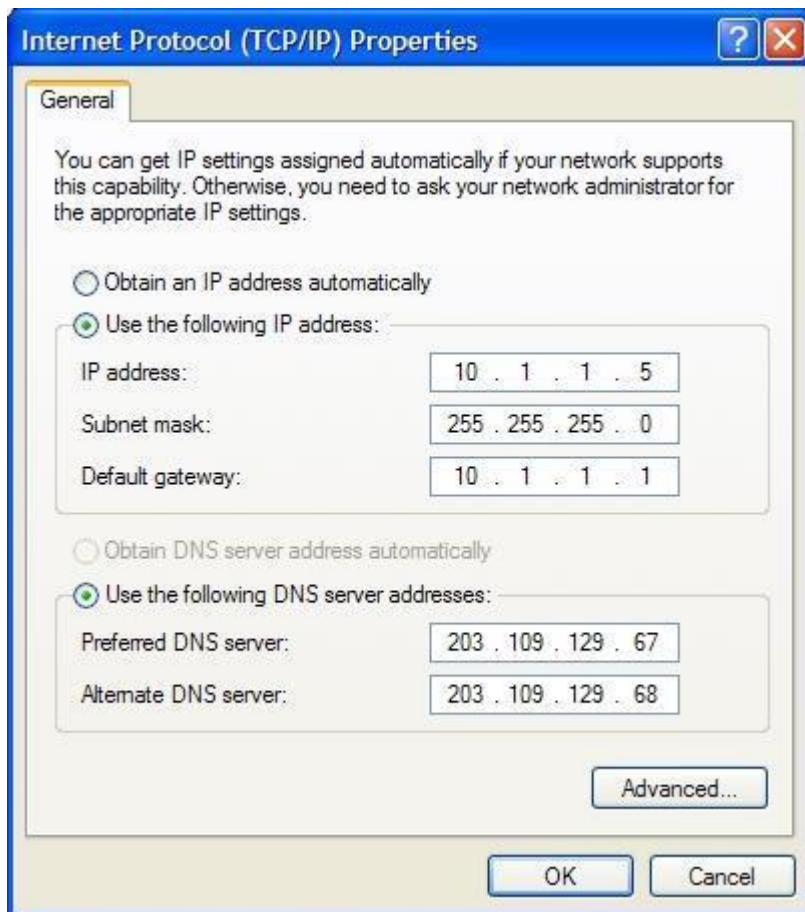


Figure 6.1 TCP/IP Properties Window (XP).

## 7 SEV View Software

The Scott Electric Vehicle (SEV) Viewer software can be used to configure all aspects of your Scott Drive Controller. The main window contains a Tool bar at the top of the window and a Tab Control with four Tab Pages. The **Drive Data** Tab page displays all the current Controller parameters down the right side of the window and two Scrolling graphs which can display a range of user selectable drive parameters.



Figure 7.1 Main Toolbar used to select various functions and windows.

The Tool Bar contains seven buttons from left to right as follows:

- Graph One parameter selection
- Graph Two parameter selection
- Settings Button
- Calibration Button
- Diagnostics Button
- Scope Button
- Shutdown Button

### 7.1 Settings Window

Click on the Settings Button in the toolbar to bring up Settings Window and select the Drive Settings Tap Page (Figure 7.2). The Scott Drive Controller operation is configured by the four groups of settings in this Window describe in the following sections. Before making any changes to the settings you should ensure the Scott Drive controller is in the Drive Standby mode (KSI Input open). After making the desired changes you must click on the **Apply Settings** button for the changes to be **saved**.

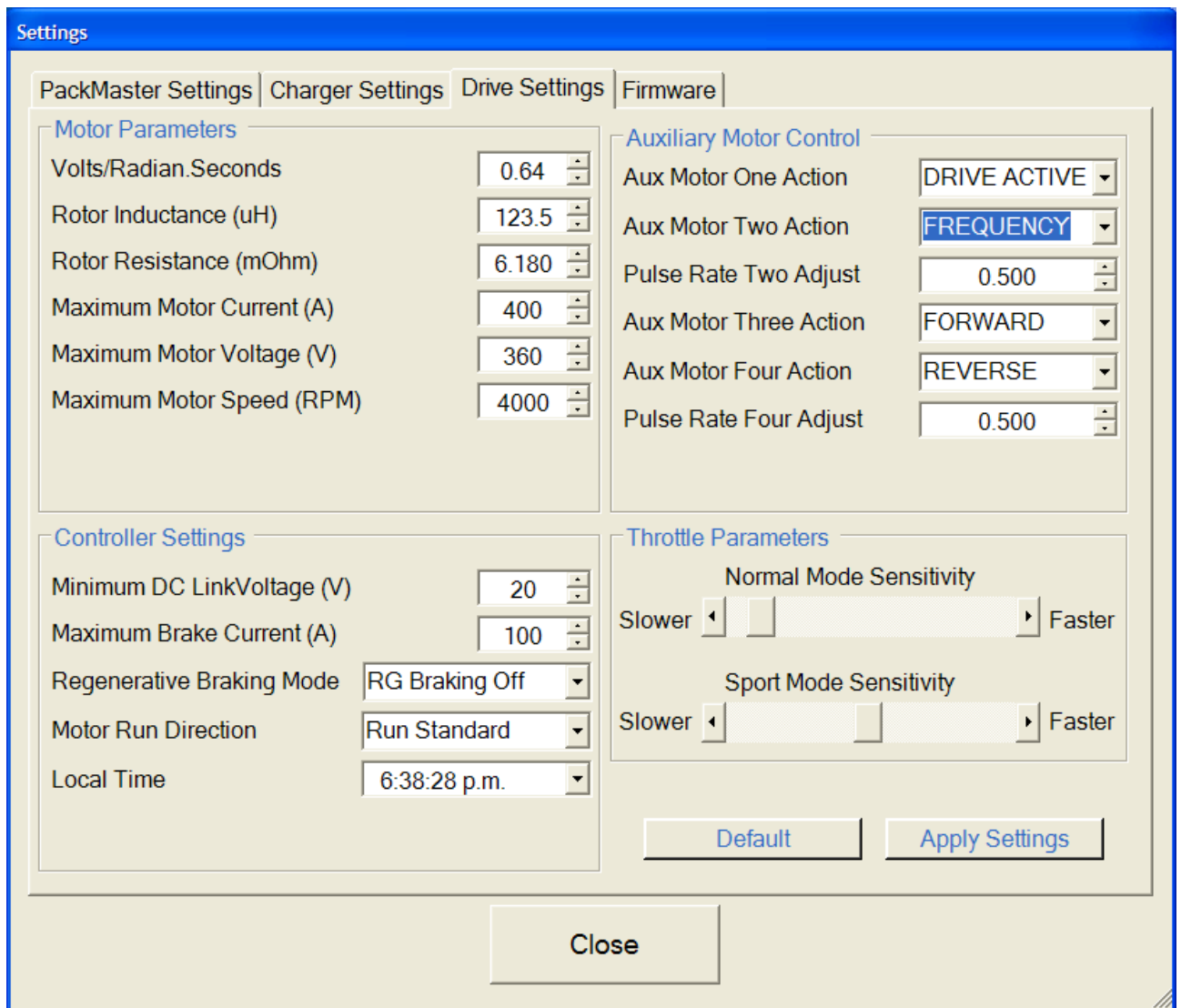


Figure 7.2 Drive Settings Tab Page.

### 7.1.1 Motor Parameters

- **Volts/Radian.Seconds:** This value should be supplied with your motor. Please note that some motor manufacturers supply this value in Volts/Hertz. If this is the case then you must convert the Volts/Hertz value to Volts/Radian.Seconds.
- **Rotor Inductance:** Can be used to tune controller for some motors.
- **Rotor Resistance:** Can be used to tune controller for some motors.
- **Maximum Motor Current:** This value should be the lesser of the Controller Current rating and the Motor Current rating.

- **Maximum Motor Voltage:** Only used if overvoltage is a possibility.
- **Maximum Motor Speed:** Maximum allowable motor speed.

### 7.1.2 Controller Settings

- **Minimum DC Link Voltage:** Can be used to protect battery from excessive discharge. Not intended to replace a full BMS system.
- **Maximum Braking Current:** This value should typically be no more than half the Maximum Motor Current. Higher values result in harsher braking characteristics.
- **Regenerative Braking Mode:** To enable regenerative braking select one of the three regenerative braking modes and make sure the regenerative disable braking input (pin [9]) is not active. The Regenerative Disable Switch Input is intended to enable the driver to easily disable regenerative braking in dangerous road conditions such as ice or heavy rain.
- **Switch Sensor Mode:** In this mode regenerative braking is activated when a micro switch or limit switch is active. As the input is digital the braking level is fixed so it is recommended to use a low braking current value.
- **Analog Sensor Mode:** In this mode a dedicated analog pot is used to provide a variable regenerative braking level. The pot may be connected directly to the brake pedal or mounted elsewhere. Please check the relevant regulations in your country when modifying the braking system in your vehicle.
- **Throttle Sensor Mode:** In this mode the Throttle Sensor pot is used as the analog input source. Typically the first 20% of the throttle travel should be used to provide a variable braking level. To correctly setup the throttle pot for regenerative braking the Gain and Offset of the analog input channel must be correctly adjusted in the Calibration Window.
- **Motor Run Direction:** Can be used to change the default rotor direction corresponding to the forward and reverse drive switch inputs.

### 7.1.3 Auxiliary Outputs

The Scott Drive 100 provides four low voltage (12V) Auxiliary Outputs capable of providing 10 Amps of continuous current (15A Peak). Each output can be configured to activate on **one** of several conditions using the SEV Monitor software. The default state of all outputs is OFF under all conditions. All four Auxiliary Outputs can be configured to activate under multiple conditions such as 'Drive Active; Forward Switch Active, Reverse Switch Active. In addition Auxiliary Output's 2 and 4 can also be configured to provide a pulsed output proportional to the Drive Frequency which is directly related to the Motor RPM for DC Brushless/AC synchronous motors. It is not recommended to use the pulse outputs with AC Induction motors.

The pulse outputs can be used to drive the Tachometers and Speedos in the instrumentation panel of your vehicle. As these outputs are controlled via low side MOSFET switches special care must be taken when connecting to the instrumentation panels in your vehicle.

### 7.1.4 Throttle Parameters

Depending on your particular motor/controller combination, gearbox ratio(s) and vehicle weight the throttle pot sensitivity can be adjusted to suit your driving style. In addition the Sport Mode button allows you quickly change from one 'Economy' mode throttle sensitivity to a second 'Sport' mode setting. If the Sport Mode input is left open the Scott Drive controller will default to the Economy mode throttle sensitivity. To activate the Sport Mode function the Sport Mode input (Pin 8) should be connected to the +5V supply (Pin 1) of the EPIC connector.

# 8 Specifications

<b>General Specifications</b>	<b>Value</b>	<b>Units</b>
Nominal DC Bus Voltage	200-425	Volts
Maximum DC Bus Voltage	450	Volts
Rated Current SD100	400	Amps
Rated Current SD200	600	Amps
Switching Frequency	10.0-15.0	kHz
Minimum Coolant Flow Rate	3.0	L/min
Drive Supply Voltage	11-16	Volts
Minimum Drive Supply Current	2	Amps
Maximum Drive Supply Current	40	Amps
Weight	14.0	kg
Dimensions	384x304x111	mm

# 9 Dimensions

