TECH/OPS

SEVCON

# SEVCON

# SC2000 MANUAL

This manual details the features of the following SC2000 core controllers and variants.

1. SC21xx Integrated Traction + Pump Controller.
2. SC22xx Standalone Traction Controller.
3. SC23xx Standalone Pump Controller.
4. SC24xx Integrated Traction Dual Motor Non Proportional Controller + Pump.
5. SC25xx Integrated Traction + Traction Dual Motor Proportional Controller.

## Revision History

| Revision | Comments |
|---|---|
| F DT | Complete rewrite to reflect the new features introduced by version 6.XX software |
| G JP | Add wiring diagrams. Change Index. Add Personalities 1.6.16 Fixed Plugging, |
| | Work Hours Count 2.2.9 and Seat 2.3.11. Remove SC26XX variant and drawings |
| | |

D.Thomson. 12th December 1997 Issue F. (SC2MAN_F.doc)
J. Punton. 22nd October 2004 Issue G. (SC2MAN_G.doc)

# CONTENTS

# 1 INTRODUCTION

1.1 The SC2000 range of Controllers use a powerful microprocessor to control two power frames - Traction (with regen or plug braking) and Pump. Both power frames are integrated within one compact enclosure and use state-of-the-art mosfet technology.

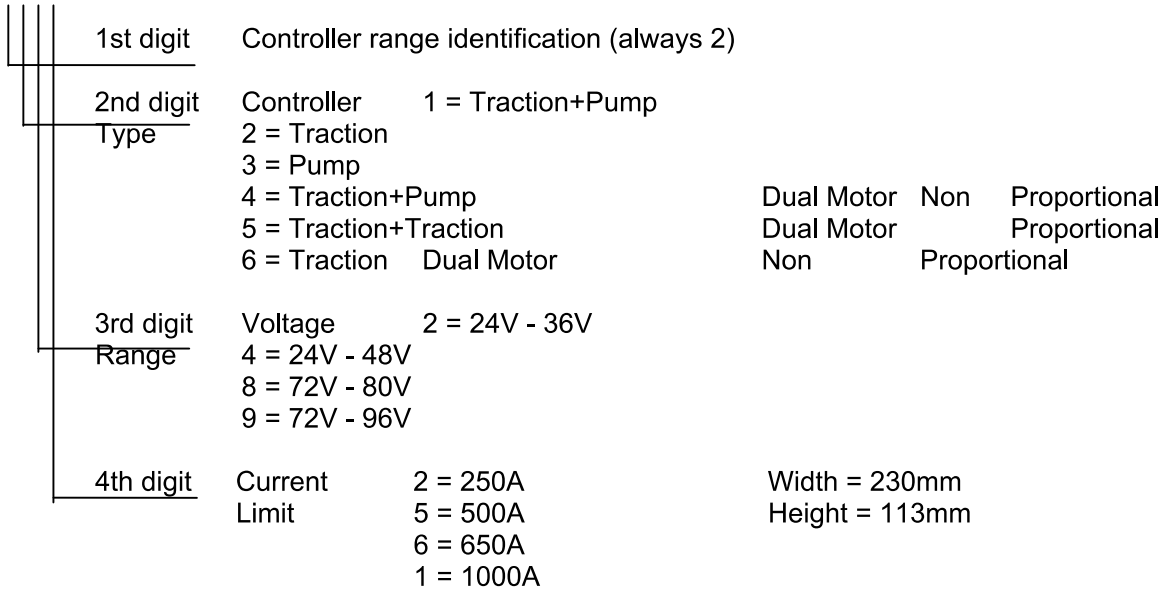
The SC2000 is available in a wide range of voltage/current variants and power-frame configurations. As well as the Traction + Pump controllers, the two power-frames within the unit can also be configured as a Traction Dual Motor non - proportional + Pump controller or as a Traction + Traction proportional unit. In addition standalone Traction or standalone Pump units can be offered.

1.2 The controllers have been designed to satisfy the requirements of the relevant UL and EC standards.

1.3 The controllers have been optimised for use with D.C. series wound motors. For other motor types contact SEVCON.

## 2 SC2000 CONTROLLER VARIENTS

SCxxxx Model number description




| MODEL | POWER | CONFIGURATION | # Power Terminals | UNIT Length |
|---|---|---|---|---|
| SC2126 | 24-36V 2x650A | Traction + Pump | 7 | 424mm (D) |
| | | | | |
| SC2145 | 24-48V 2x500A | Traction + Pump | 7 | 360mm (C) |
| SC2445 | " | Traction Dual Motor Non Proportional + Pump | 9 | 424mm (D) |
| SC2545 | " | Traction + Traction Dual Motor Proportional | 8 | 360mm (C) |
| SC2542 | 24-48V 2x250A | Traction + Traction Dual Motor Proportional | 8 | 360mm (C) |
| | | | | |
| SC2146 | 24-48V 2x650A | Traction + Pump | 7 | 424mm (D) |
| SC2446 | " | Traction Dual Motor Non Proportional + Pump | 9 | 488mm (E) |
| | | | | |
| SC2185 | 72-80V 2x500A | Traction + Pump | 7 | 488mm (E) |
| SC2485 | " | Traction Dual Motor Non Proportional + Pump | 9 | 552mm (F) |
| SC2585 | " | Traction + Traction Dual Motor Proportional | 8 | 488mm (E) |
| | | | | |
| SC2186 | 72-80V 2x650A | Traction + Pump | 7 | 552mm (F) |
| SC2586 | " | Traction + Traction Dual Motor Proportional | 8 | 552mm (F) |
| | | | | |
| SC2286 | 72-80V 1x650A | Traction | 5 | 360mm (C) |
| SC2386 | " | Pump | 4 | 360mm (C) |
| | | | | |
| SC2296 | 72-96V 1x650A | Traction | 5 | 360mm (C) |
| SC2396 | " | Pump | 4 | 360mm (C) |
| | | | | |
| SC2291 | 72-96V1x1000A | Traction | 5 | 488mm (E) |

# 3 CONTROLLER FEATURES

3.1 The SC2000 range of controllers offer the following features:

* 24-48V, 72-80V and 72-96V operation. Current limits of 500, 650A and 1000A.
* Enclosed unit to IP34 with Field-replaceable logic.
* Traction + Pump motor controllers in one enclosure.
* Also standalone Traction and standalone Pump controllers available.
* Microprocessor control.
* High frequency (silent operation).
* Start-up safety sequence and Static return to Off (SRO).
* Internal watchdog monitoring microprocessor operation.
* Arcless contactor switching and built-in contactor coil suppression.
* Use of 24V contactors at all voltages possible.
* Switch inputs configurable to be normally open or normally closed.
* Active low inputs switched to B-, or active high inputs switched to B+ (Factory option).
* Low input impedance for protection against water (active low inputs).
* Thermally compensated current limit.
* Selectable accelerator characteristics.
* Adjustable creep speed.
* Bypass with over current drop out.
* Field weakening.
* Seat switch timer.
* Power steer contactor and timer.
* Regenerative or Plug braking only, both high frequency and silent.
* Braking proportional to accelerator or optionally non proportional.
* Electric braking in neutral.
* Electric braking with brake pedal. (Switch or Potentiometer required)
* Under-voltage and over-voltage protection.
* Accelerator wire-off detect.
* Flexible accelerator interface with minimum/maximum voltages programmable.
* Inching and timed burst-inching facilities.
* Economy pot input initiating either increased acceleration delays or reduced current limit.
* Short-circuit and open-circuit contactor detect.
* 2 Traction cut-back speeds with independent acceleration delays.
* 7 pump speeds with Priority, Additive and Compensation features available.
* Inhibit input to disable pump operation, from external source such as BDI.
* Independent Power Steer speed and compensation settings, with ramp up/down delays.
* Hardware and Software fail-safe protection + autofailsafe check every power-up.
* Contactor drive short circuit detection.
* Fault detection with LED display.
* Serial communications bus (CANbus).
* Adjustments made using plug-in calibrator with optional levels of access.
* Diagnostics & Service information with calibrator.
* Hours Counter displaying Key Switch, Pump and Traction pulsing hours on calibrator.
* BDI. Battery discharge indicator with adjustable warning and cut out levels.
* Dual motor non proportional and proportional variants with steer switch or steer pot inputs.
* Dual Motor steer angles can be adjusted to match truck geometry when using a steer pot.
* Dual Motor independently adjustable ramp-up / ramp-down settings for smooth cornering.
* Controller extrusion has ‘T’ slots for direct mounting of Albright contactors.
* Speed limit facility optionally available with speed sensor.
* Resettable Service and Fault logs.
* Non-English Languages selectable on calibrator.
* Standard Dashboard Display available displaying BDI, Hours, Steer angle and diagnostics.
* Full Feature Dashboard Display also available. As above but custom LCD with graphics.
* Setup menu on calibrator to enable and disable common options.

# 4 SAFETY

4.1 Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures. THE VEHICLE MANUFACTURER'S MANUAL SHOULD BE CONSULTED BEFORE ANY OPERATION IS ATTEMPTED.

4.2 The SC2000 controller contains a triple fail-safe system to give a high level of safety. If the diagnostic LED is not illuminated or flashes, the safety circuit may have tripped and the truck may not drive.

4.3 To ensure continued safety of the SC2000 system, the fail-safe circuit should be checked whenever the truck is serviced (See 4.7). The period between checks should not exceed 3 months.

4.4 THE BATTERY MUST BE DISCONNECTED BEFORE REPLACING OR ATTEMPTING ANY REPAIRS OF THE CONTROLS.

4.5 Before working on the controls disconnect the battery and connect the B+ and B- controller terminals via a 10 ohm 25 watt resistor to discharge the internal capacitors.

4.6 Never connect the controller to a battery with it's vent caps removed as an arc may occur due to the controller's internal capacitance when it is first connected.

4.7 FAIL-SAFE CHECK:

4.7.1 Ensure the drive wheels are CLEAR OF THE FLOOR AND FREE TO ROTATE.

4.7.2 Switch on, select seat switch, release brake, select direction and FS1, the wheels should rotate and the diagnostic LED should give a steady illumination.

4.7.3 Switch off, disconnect battery and connect the F1 and B- terminals together with, at least, 10mm$^2$ cable. Ensure that no other fault that would allow drive is present.

4.7.4 Reconnect battery, switch on key with direction in neutral. The LED should stay off. Select a direction and check that the direction contactors do not close and the wheels do not rotate.

4.7.5 Switch off at key and remove the F1/B- connection. Switch on at key, reselect the power-up sequence and check that the LED illuminates and the truck wheels rotate.

IF THE TRUCK DRIVES IN 4.7.4 THE CONTROLLER IS FAULTY AND MUST BE REPLACED.

4.8 NOTES:

4.8.1 As blow-out magnets are fitted to contactors (except 24V) ensure that no magnetic particles can accumulate in the contact gaps and cause malfunction. Ensure that contactors are wired with the correct polarity to their power terminals as indicated by the + sign on the top moulding.

4.8.2 The SC2000 controller must NOT be used with permanently-connected on-board chargers or damage to the system may result.

# 5 TECHNICAL SPECIFICATIONS

## 5.1 Environmental

| | | |
|---|---|---|
| 5.1.1 | Protection: | The enclosure is protected to IP34. 1st digit (3) = Protection against objects > 2.5mm entering controller enclosure. 2nd digit (4) = Protection against low pressure jets of water in any direction. Limited ingress permitted. |
| 5.1.2 | Vibration: | 6G, 40-200Hz for 1 hour, in x,y and z planes. |
| 5.1.3 | Operating Temperature: | -30$^{O}$C to +40$^{O}$C ambient around controller. |
| 5.1.4 | Storage Temperature: | -40$^{O}$C to +70$^{O}$C. |
| 5.1.5 | Humidity: | 95% maximum, non-condensing. |
| 5.1.6 | Humidity Resistance: | No functional defects after controller is left at 60$^{O}$C and 100% humidity for one hour after freezer use (-30$^{O}$C minimum). |

## 5.2 Mechanical

| | | | | |
|---|---|---|---|---|
| 5.2.1 | Unit length/weight | A unit | n/a | n/a |
| | | B unit | n/a | n/a |
| | | C unit | 360 mm | 7.50 kg |
| | | D unit | 424 mm | 9.25 kg |
| | | E unit | 488 mm | 11.00 kg1. |
| | | F unit | 552 mm | 12.75 kg |
| 5.2.2 | Unit width: | All units | 230mm | |
| 5.2.3 | Unit height: | All units | 93 mm (excluding power terminals). 113 mm (including power terminals). | |
| 5.2.4 | Enclosure: | Aluminium ‘U’ extrusion forming base and walls with plastic extruded top cover. | | |
| 5.2.5 | Contactor mounting: | Extrusion has 2 M6 ‘T’ slots running down the length of the controller for the direct mounting of Albright contactors. | | |
| 5.2.6 | Fuse mounting: | Using suitable brackets fuses can also be fitted to the ‘T’slot. | | |
| 5.2.7 | Power connections: | Aluminium vertical power bushes for M8 connection. | | |
| 5.2.8 | Fixings: | 6 x M6 clearance slots. | | |

## 5.3 Electrical

5.3.1 Voltage specifications:

| Model | Voltage | Nominal battery voltage | Operating voltage | 30 sec. voltage surge |
|---|---|---|---|---|
| SC2x2x | 24V Units | 24-36V | 14.5-45V | 50V |
| SC2x4x | 48V Units | 24-48V | 14.5-70V | 80V |
| SC2x8x | 80V Units | 72-80V | 43.0-100V | 115V |
| SC2x9x | 96V Units | 72-96V | 43.0-130V | 150V |

5.3.2 Current specifications:

| Model | Power | Current limit (1 min) Trac.+ Pump | Safe operating Area (SOA) | Continuous Current 1 Hour rating, with unit mounted on an aluminium baseplate 780x380x10mm, at 20°C ambient. |
|---|---|---|---|---|
| SC2x26 | 24V 2x650A | 650A | 30 - 60% | 225A (1 side only) |
| SC2x45 | 48V 2x500A | 500A | 30 - 60% | 170A (1 side only) |
| SC2x46 | 48V 2x650A | 650A | 30 - 60% | 225A (1 side only) |
| SC2x85 | 80V 2x500A | 500A | 0 - 50% | 170A (1 side only) |
| SC2x86 | 80V 1x650A | 650A | 0 - 45% | 225A (1 side only) |
| SC2x96 | 96V 1x650A | 650A | 0 - 45% | 225A (1 side only) |

5.3.3 Switching Frequency: 15.7 kHz (Traction Drive and Braking and Pump).

5.3.4 Electrical Isolation: Enclosure to any live part = 1kV. Controller internal insulation specified at > 10MΩ @500V DC. Dielectric strength 1000V @ 50Hz for 1 Minute

5.3.5 Battery Polarity: An internal diode fitted in the keyswitch line will prevent line contactor closure if the battery positive and negative connections are reversed. When a line contactor is used no damage to the controller will result.

5.3.6 Switch/Digital Inputs: Connector 1 (24 way) Pins:-
1, 2, 3, 4, 5, 6, 7, 8, 13, 14, 15, 16, 17, 18, 19 & 20

Operation: Active-low (The input becomes active when connected to battery negative, otherwise inactive).

Voltage Range:

| | |
|---|---|
| Low (Closed) | -1.0 to +1.8 V |
| High (Open) | +4.5 to +150 V (or open-circuit). |

Input Impedance: Max. resistance to ground for a 'low' = 500 Ω.
Min. resistance to ground for a ‘high’ = 2.7 kΩ

Note : negative switch returns must be connected to controller B- terminal and not at battery negative.

5.3.7 Active-high Inputs: The switch/digital inputs are available as a factory set, hardware active-high option. Active-high inputs are higher impedance and are more susceptible to moisture problems.

Active-low inputs are recommended.

Operation: Active-high (The input becomes active when connected to battery positive, otherwise inactive).

Voltage Range:

| | |
|---|---|
| Low (Open) | -1.0 to 4.0 V (or open circuit) |
| High (Closed) | +8.75 to 150 V |

Input Impedance: Max input impedance = 35 kΩ

5.3.8 Analogue Inputs: Connector A (24 way) pins:- 9, 10, 21 & 22

| | | |
|---|---|---|
| | | Three of the above inputs, pins 9, 10 & 21 have supply outputs associated with them, pins 11, 12 & 23 respectively. Various connection options are available. |
| | Voltage Range: | 0V - 5.0V<br><br>Using the calibrator, the minimum and maximum levels can be defined to equal any two voltages in the above range. |
| | Option 1: | Potentiometers wired as '2 wire' systems between the input pins and B-ve. The wiper will be connected to either the input or B-ve. Leave the associated supply pin unconnected. This option available on all 4 analogue inputs.<br><br>Nominal potentiometer resistance range: 1k to 10k. |
| | Option 2: | Potentiometers wired as '3 wire' systems will be connected between B-ve and the associated supply pin, with the wiper connecting to the input pin.<br>This option only available on input pins 9, 10 & 21.<br>Nominal potentiometer resistance range: 2K to 20K. |
| | Option 3: | Voltage source type inputs, such as solid state accelerator units that derive there own supply, should feed directly into the analogue input pin. Connecting the associated supply pin to B-ve disables an internal pull up resistor and presents the analogue pin as a high impedance input.<br><br>This option only available on input pins 9, 10 & 21<br><br>Nominal voltage input range: 0 to 5.0V |
| | Absolute Max. Voltages: | -1 V to +150 V. |
| | An example of each connection option is shown in the light wiring diagram (figure 1) | |
| 5.3.9 | Supply output: | Connector A (24 way) pin 24<br>An unregulated +12V power supply is available for supplying speed sensors etc. Contact SEVCON for details before using this pin. |
| 5.3.10 | Contactor Drives: | Connector B (12 way) pins:- 1, 2, 3, 4, 5, 6, 7 & 8 |
| | Maximum Current: | 2A. |
| | Protection: | Drives are protected against direct connection to B+ and B-. |
| | Suppression: | Coil suppression built-in. |
| | +ve coil supply: | Connector B (12 way) pin 11<br><br>All the contactor coils must be supplied from this pin and NOT from the keyswitch or B+ directly.<br><br>There are a maximum of 8 contactor drives available. |

# 6 CONTROLLER CONNECTIONS

## 6.1 Power Connections (Figs. 2 to 7)

Power wiring must be made with 35mm$^2$ cable (minimum).

6.1.1 **Controller Connections** - These are made via M8 terminals depending on unit configuration, as follows:

**All Controllers:**
B+ Connected to Battery positive via the fuse and line contactor (if fitted).
B- Connected to Battery negative.

**Traction Controllers, not Dual Motor:**
A1 Connected to the normally closed contacts of the direction contactors
F1 Connected to the negative end of the Traction motor field.
S1 Connected to the positive end of the Traction motor field.

**Pump Controllers:**
F2 Connected to the negative side of the Pump motor.
S2 Connected to the positive side of the Pump motor.

**Traction Controllers, Dual Motor Non-Proportional:**
D1 Connected to the positive end of the Right Traction Motor Field.
D2 Connected to the positive end of the Left Traction Motor Field.

**Traction Controllers, Dual Motor Proportional:**
A2 As per A1 for second Traction Motor.
F2 As per F1 for second Traction Motor.
S2 As per S1 for second Traction Motor.

6.1.2 **Contactor Connections**

| | |
|---|---|
| Line (Optional) | + terminal to Fuse, other terminal to the B+ terminal of the controller and the regen contactor if fitted. |
| Direction | See power wiring diagrams (figs 2,3,5,6,7) |
| Regen (Optional) | Common to Direction contactor, normally open contact to controller B+ terminal, normally closed contact to controller B- terminal. |
| Power Steer (Optional) | + terminal to battery positive via fuse, other terminal to the power steer motor. |
| Bypass (Optional) | + terminal to F1 terminal of controller, other terminal to Battery Negative. |
| Field Weakening (Optional) | + terminal via resistor to S1 terminal of controller, other terminal to F1 terminal of controller. |
| Pump Bypass (Optional) | + terminal to F2 terminal of controller, other terminal to B-ve. |
| Pump F.Weakening | + terminal to top of Field and other terminal to F2. |

Note1: Line contactor is optional but can be fitted to offer reverse battery protection, minimise arcing when the battery connector is inserted and to provide a mechanical break for a Pump Controller.

Note2: Any 2 of the Optional contactors (except Line) can be reassigned for use as the second set of direction contactors for dual motor traction systems.

Note3: For dual motor non proportional systems the balancing contactor will be required.

### 6.1.3 Contactor Types (8 drives available)

The recommended contactors for controllers with current limits up to 500A are:

| | | |
|---|---|---|
| Line | Albright SW200 | Continuous Rating |
| Direction (Forward/Reverse) | Albright DC182 | Intermittent Rating |
| Regen | Albright SW181 | Intermittent Rating |
| Traction Bypass | Albright SW180 | Intermittent Rating |
| Field Weakening | Albright SW80 | Intermittent Rating |
| Power Steer | Albright SW80 | Continuous Rating |
| Pump Bypass | Albright SW180 | Intermittent Rating |

Recommended contactors for current limits of above 500A are:

| | | |
|---|---|---|
| Line | Albright SW200 | Continuous Rating |
| Direction(Forward/Reverse) | Albright SW202 | Intermittent Rating |
| Regen | Albright SW201 | Intermittent Rating |
| Traction Bypass | Albright SW200 | Intermittent Rating |
| Field Weakening | Albright SW80 | Intermittent Rating |
| Power Steer | Albright SW80 | Continuous Rating |
| Pump Bypass | Albright SW180 | Intermittent Rating |

It is recommended that 24 V contactors are used together with the chopping feature.

6.1.4 **Fuse Ratings -** The recommended fuse ratings are:

| | | |
|---|---|---|
| Main | 500 or 750A | (air-break) |
| Power Steer | 50A | (air-break) |
| Control | 10A | (with the specified contactors) |
| BDI Measure input (con. B, pin 10) | 1A | |

6.1.5 **Regen Diode -** available from SEVCON (840/44245) and connected as follows:

| | |
|---|---|
| Cathode | Lead connected to regen Contactor common terminal. |
| Anode | Stud screwed into regen Contactor B-. |

## 6.2 Light Wiring Connections (Fig. 1)

### 6.2.1 Connector A - 24 way

| Pin | Main Function | Secondary Function | Pin Type | |
|---|---|---|---|---|
| 1. | Forward Switch | | Digital | i/p |
| 2. | Reverse Switch | | Digital | i/p |
| 3. | FS1 Switch | | Digital | i/p |
| 4. | Seat Switch | | Digital | i/p |
| 5. | Handbrake Switch | | Digital | i/p |
| 6. | Speed Cutback 1 Input | | Digital | i/p |
| 7. | Speed Cutback 2 Input | (Dual Motor Outer sw) | Digital | i/p |
| 8. | Pump Inhibit Input | | Digital | i/p |
| 9. | Analogue2 Input | | Analogue | i/p |
| 10. | Analogue1 Input | | Analogue | i/p |
| 11. | Analogue2 Supply | | Supply | o/p |
| 12. | Analogue1 Supply | | Supply | o/p |
| 13. | Speed Encoder | | Digital | i/p |
| 14. | Power Steer Trigger Input | | Digital | i/p |
| 15. | Pump Switch 2 | | Digital | i/p |
| 16. | Pump Switch 3 | | Digital | i/p |
| 17. | Pump Switch 4 | | Digital | i/p |
| 18. | Pump Switch 5 | | Digital | i/p |
| 19. | Pump Switch 6 | (Inch Forward/DM Inner Left sw) | Digital | i/p |
| 20. | Pump Switch 7 | (Inch Reverse/DM Inner Right sw) | Digital | i/p |
| 21. | Analogue4 Input | | Analogue | i/p |
| 22. | Analogue3 Input | | Analogue | i/p |
| 23. | Analogue4 Supply | | Supply | o/p |
| 24. | +12V Supply | | Supply | o/p |

The function of the analogue inputs depends on the type of SC2000 controller and is defined by the table below

| Controller | Analogue1 | Analogue2 | Analogue3 | Analogue4 |
|---|---|---|---|---|
| **SC21XX** | Traction | Footbrake | Economy | Pump |
| **SC22XX** | Traction | Footbrake | Economy | Not Used |
| **SC23XX** | Not Used | Not Used | Not Used | Pump |
| **SC24XX** | Traction | Steer Pot. | Footbrake | Pump |
| **SC25XX** | Traction | Steer Pot. | Footbrake | Economy |

*Note The footbrake switch (if required) should be connected in series with the footbrake potentiometer (if fitted), and Pump Switch 1 (if required) should be connected in series with the pump accelerator (if fitted).

### 6.2.2 **Connector B - 12 way**

| Pin | Main Function | Dual Motor Function | Pin Type | |
|---|---|---|---|---|
| 1. | Line Contactor | | Digital | o/p |
| 2. | * Forward Contactor | (DM Right Motor Fwd) | Digital | o/p |
| 3. | * Reverse Contactor | (DM Right Motor Rev) | Digital | o/p |
| 4. | Regen Contactor | | Digital | o/p |
| 5. | * Bypass Contactor | (DM Left Motor Fwd) | Digital | o/p |
| 6. | * Field Weakening Contactor | (DM Left Motor Rev) | Digital | o/p |
| 7. | Power Steer Contactor | | Digital | o/p |
| 8. | * Pump Bypass, F.Weak or LED o/p | (DM Balance/Bypass Cont.). | Digital | o/p |
| 9. | Regen Contactor Detect input | | Digital | i/p |
| 10. | BDI Battery Measure input | | Analogue | i/p |
| 11. | Contactor Positive Supply | | Supply | o/p |
| 12. | B+ve Keyswitch input | | Supply | i/p |

### 6.2.3 Connectors C and D (6 way)

These two connectors are connected in parallel and provide input/output capability for the Calibrator, Displays and other equipment needing to communicate with the controller. They are part of a serial Controller Area Network bus system and protocol (CANbus). The Calibrator can be connected to either of these connectors.

All the pins are protected against misconnection to each other and B-ve. The sockets provide physical protection against short circuits to B+ve.

| Pin | Main Function | Secondary function | Pin Type | |
|---|---|---|---|---|
| 1. | 10.5 V | (SC2000 select) | Digital | i/p |
| 2. | 0 V | (-ve supply) | Supply | o/p |
| 3. | 10.5 V | (SC2000 select) | Digital | i/p |
| 4. | 10.5 V | (+ve supply) | Supply | o/p |
| 5. | CAN High | (Data) | Digital | i/o |
| 6. | CAN Low | (Data) | Digital | i/o |

### 6.2.4 CAN (Controller Area Network) Overview

The main applications for CAN communications are automotive and industrial electronics where high speed, noise immune serial communications are required to work reliably in high vibration and high temperature environments.

Sevcon's CAN system is defined as CAN 2.0A (Basic CAN, error active) and is implemented using a Philips Semiconductor chip-set with an 80C250 transceiver chip. The SC2000 CAN protocol sets the baud rate to be 100K bits per second.

CAN is extremely flexible and versatile, allowing multi-master operation in a serial communication network with an almost unlimited number of nodes. Data rates of up to 1 Mbit/s are possible transmitting over distances of up to 40 meters, with a very low probability of undetected errors. CAN is basically a 2-wire twisted-pair differential system with 10V5 and 0v supply rails. Connections are made via FCC-68 telephone type sockets to help prevent against mis-connection and to provide easy connections. Each controller has 2 sockets to allow full "daisy chaining" loop connections. The loop network is terminated at each end with a 120R resistor, which is automatically provided inside the controller.

Presently the CANbus is used to communicate with the calibrator. It can be used to communicate with a dashboard display and for remote control from a host PC. Long term, communications with auxiliary controllers and equipment will be possible.

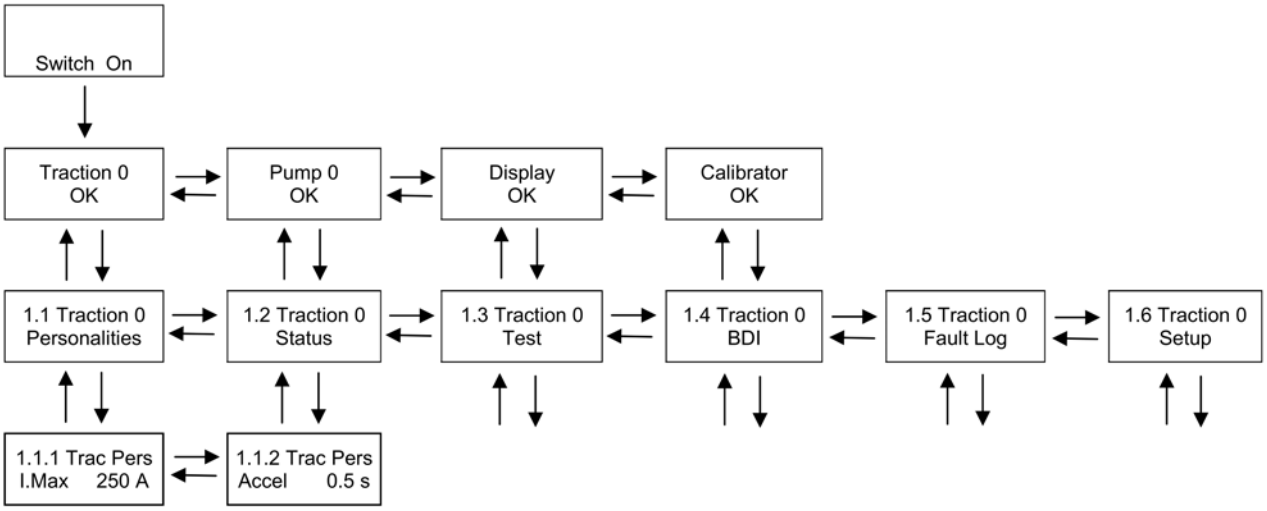
E.g. Battery Chargers, Standalone Power Steer Controllers, Controller I/O expanders ...etc. . At present it is possible to connect up to 15 auxiliary pieces of equipment onto the CAN bus.

# 7 CALIBRATOR AND ADJUSTMENTS

A sophisticated, yet easy to use hand held adjustment unit, called the Can Calibrator is used to make adjustments to the controller and select configurations. The CAN Calibrator is also used as a diagnostic tool displaying the status of all voltages, currents and temperatures within the controller together with the condition of all the controller's switch and analogue inputs.

The diagram below describes how the CAN Calibrator is used. The left and right arrows move between screens on the same level. The up and down arrows move between levels and the + and - buttons increment or decrement the parameters by the amount indicated in the STEP column of the following tables.

The calibrator can be specified to have various levels of access to certain adjustments. A multi-language version is available for newer controllers.

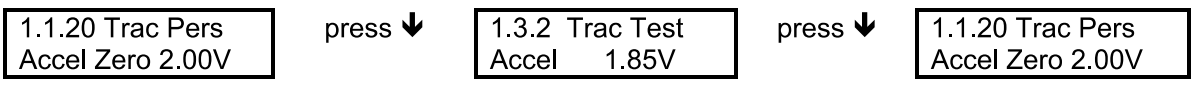



### 7.1.1 Traction Personalities (Controller Adjustments)

| Cal.Ref | Parameter Adjusted | Min setting (all units) | Max.setting (500 A unit) | Max.setting (650 Aunit) | Step size (all units) |
|---|---|---|---|---|---|
| 1.1.1 | Current limit | 50 A | 500 A | 650 A | 10 A |
| 1.1.2 | Acceleration delay | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.3 | Deceleration delay | 0.1 s | 0.5 s | 0.5 s | 0.1 s |
| 1.1.4 | Creep speed | 0 % | 25 % | 25 % | 1.0 % |
| 1.1.5 | Maximum speed | 0 % | 100 % | 100 % | 1.0 % |
| 1.1.6 | Cutback speed 1 | 0 % | 100 % | 100 % | 1.0 % |
| 1.1.7 | Acceleration delay1 | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.8 | Cutback speed 2 | 0 % | 100 % | 100 % | 1.0 % |
| 1.1.9 | Acceleration delay2 | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.10 | Direction Brake current | 50 A | 500 A | 650 A | 10 A |
| 1.1.11 | Neutral Brake Current | 10 A (0 disables) | 500 A | 650 A | 10 A |
| 1.1.12 | Footbrake Current | 10 A (0 disables) | 500 A | 650 A | 10 A |
| 1.1.13 | Bypass Over Current | 10 A (0 disables) | 750 A | 970 A | 10 A |
| 1.1.14 | Field Weak Pull In | 50 A | 500 A | 650 A | 10 A |
| 1.1.15 | Field Weak Drop Out | 50 A | 500 A | 650 A | 10 A |
| 1.1.16 | Power Steer Delay | 0 s | 50 s | 50 s | 1.0 s |
| 1.1.17 | Seat Switch Delay | 0 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.18 | Regen Time | 0 ms (0=plug only) | 350 ms | 350 ms | 10 ms |
| 1.1.19 | Brake Constant Factor | 0 | 25.5 | 25.5 | 0.1 |
| 1.1.20 | Accelerator Zero Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.21 | Accelerator Full Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.22 | Footbrake Pot Zero Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.23 | Footbrake Pot Full Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.24 | Economy Pot Zero Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.25 | Economy Pot Full Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.26 | Steer Pot left Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.27 | Steer Pot right Level | 0 V | 5.5 V | 5.5 V | 0.02 V |
| 1.1.28 | Speed Limit | 0 KPH (0 disables) | 60 KPH | 60 KPH | 1 KPH |
| 1.1.29 | Dual Motor Inner Angle | 5 ° | 85 ° | 85 ° | 1.0 ° |
| 1.1.30 | Dual Motor Inner Ramp | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.31 | Dual Motor Outer Angle | 5° | 85 ° | 85 ° | 1.0 ° |
| 1.1.32 | Dual Motor Outer Ramp | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.33 | Inch Speed | 0 % | 25 % | 25 % | 1 % |
| 1.1.34 | Burst Inch Delay | 0 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.35 | Bypass Delay | 0.0 s | 5.0 s | 5.0 s | 0.1 s |
| 1.1.36 | Plugging Threshold | 50 | 255 | 255 | 1.0 |

Note 1: Depending on controller type and configuration some of the above may not be displayed.

Note 2: pressing the calibrator “down arrow” key from the potentiometer zero and full personalities (1.1.20 to 1.1.27, and 2.1.23 to 2.1.24) jumps directly to the associated voltage measurement in the test menu. Pressing this key from the test menu jumps back to the associated zero level personality. For example:



### 7.1.2 Traction Status Information

| Cal.Ref. | Parameter Displayed | Min.Display | Max.Display | Step size | Log Info. |
|---|---|---|---|---|---|
| 1.2.1 | Battery Voltage | 0 V | 127 V | 0.1 V | + |
| 1.2.2 L/R | Traction Motor Voltage | 0 V | 127 V | 0.5 V | |
| 1.2.3 L/R | Traction Motor Current | 0 A | 1200 A | 6 A | + |
| 1.2.4 L/R | Traction Controller Temp. | -30 °C | +225 °C | 1 °C | + - |
| 1.2.5 L/R | Traction Mosfet Voltage | 0 V | 127 V | 0.5 V | |
| 1.2.6 | Capacitor Voltage | 0 V | 127 V | 0.5 V | |
| 1.2.7 | Speed Sensor Indication | 0 KPH | 60 KPH | 1.0 KPH | |
| 1.2.8 | Key Switch Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hrs | |
| 1.2.9 | Traction Pulsing Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hrs | |
| 1.2.10 | Pump Contactor Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hrs | |
| 1.2.11 | Work Hours (Trac. or Pump) | 0 Hrs | 65279.9 Hrs | 0.1 Hrs | |
| - | Service Log Reset | press + followed by - to reset service log | | | |

Note 1: On Dual Motor Controllers L and R denote two displays for both left and right motors.
Note 2: Log Info shows where the + and - keys can be used to access the service max and min data.

### 7.1.3 Traction Test Information

| Cal.Ref | Input Displayed | | Min. Display | Max. Display | Step Size |
|---|---|---|---|---|---|
| 1.3.1 | Accelerator % | Range | 0 % | 100 % | 1 % |
| 1.3.2 | Accelerator Voltage | Range | 0.0 V | 5.7 V | 0.1 V |
| 1.3.3 | Footbrake Pot. % | Range | 0 % | 100 % | 1 % |
| 1.3.4 | Footbrake Pot. Voltage | Range | 0.0 V | 5.7 V | 1 V |
| 1.3.5 | Economy Pot. % | Range | 0 % | 100 % | 1 % |
| 1.3.6 | Economy Pot. Voltage | Range | 0.0 V | 5.7 V | 0.1 V |
| 1.3.7 | Dual Motor Steer Pot. % | Range | 0 % | 100 % | 1 % |
| 1.3.8 | Dual Motor Steer Pot. V | Range | 0.0 V | 5.7 V | 0.1 V |
| 1.3.9 | Forward | Switch | Open | Closed | - |
| 1.3.10 | Reverse | Switch | Open | Closed | - |
| 1.3.11 | FS1 | Switch | Open | Closed | - |
| 1.3.12 | Seat | Switch | Open | Closed | - |
| 1.3.13 | Handbrake | Switch | Open | Closed | - |
| 1.3.14 | Speed Cutback 1 | Switch | Open | Closed | - |
| 1.3.15 | Speed Cutback 2 | Switch | Open | Closed | - |
| 1.3.16 | Power Steer Trigger Input | Switch | Open | Closed | - |
| 1.3.17 | Inch Forward | Switch | Open | Closed | - |
| 1.3.18 | Inch Reverse | Switch | Open | Closed | - |
| 1.3.19 | Dual Motor Inner Left | Switch | Open | Closed | - |
| 1.3.20 | Dual Motor Inner Right | Switch | Open | Closed | - |
| 1.3.21 | Dual Motor Outer | Switch | Open | Closed | - |
| 1.3.22 | Pump Contactor Trigger | Switch | Open | Closed | - |
| 1.3.23 | Software Version/Revision | | 000.00 | 999.99 | - |
| 1.3.24 | Controller Serial Number | | 00000000 | 99999999 | - |

Note: As with the personalities, only relevant switch tests will be shown.

### 7.1.4 BDI Adjustments (if enabled in setup menu)

| Cal.Ref. | Parameter Adjusted/Displayed | Min Setting | Max. Setting | Step Size. |
|---|---|---|---|---|
| 1.4.1 | xxx % Charge remaining | display only | | |
| 1.4.2 | Battery Volt xx V | 24 V | 96 V | 2 V |
| 1.4.3 | Reset x.xx V/Cell | 2.00 V/Cell | 2.50 V/Cell | 0.01 V/Cell |
| 1.4.4 | Empty x.xx V/Cell | 1.50 V/Cell | 1.99 V/Cell | 0.01 V/Cell |
| 1.4.5 | Warning xx % | 0 % | 90% | 1.0 % |
| 1.4.6 | Cutout xx % | 0 % | 90% | 1.0 % |

### 7.1.5 Fault Log

Can be disabled via setup menu. See section 9 for more details.

### 7.1.6 Setup Menu (Enables/Disables features)

| Cal.Ref. | Feature | Options |
|---|---|---|
| 1.6.1 | Contactor Chopping | 24 V / On / Off |
| 1.6.2 | Accelerator Type | Linear / Curved / 2* Slope/ Crawl |
| 1.6.3 | BDI | On / Off |
| 1.6.4 | Power Steer Trigger | None to FS1+Dir+Brake+Seat |
| 1.6.5 | Economy Cuts Traction Current | On / Off |
| 1.6.6 | Bypass in Current Limit | On / Off |
| 1.6.7 | SRO | On / Off |
| 1.6.8 | Braking | Proportional / Constant |
| 1.6.9 | Seat Switch Cuts Pump | On / Off |
| 1.6.10 | Fault Log | On / Off |
| 1.6.11 | Service Log | On / Off |
| 1.6.12 | Node Number | 0 to 15 |
| 1.6.13 | Full Speed | 5 to 60 KPH in 1 KPH steps |
| 1.6.14 | Probe Frequency | 10 to 200 Hz in 1 Hz steps |
| 1.6.15 | Cut2 Lmt Spd | On / Off |
| 1.6.16 | Fixed plugging | On / Off |

Note: Changes only take effect after a key-switch recycle

### 7.2.1 Pump Personalities (Controller Adjustments)

| Cal.Ref | Parameter Adjusted | Min setting (all units) | Max.setting (500 A units) | Max.setting (650 A units) | Step size (all units) |
|---|---|---|---|---|---|
| 2.1.1 | Current Limit | 50 A | 500 A | 650 A | 10 A |
| 2.1.2 | Ramp Up Delay | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 2.1.3 | Ramp Down Delay | 0.1 s | 0.5 s | 0.5 s | 0.1 s |
| 2.1.4 | Creep Speed | 0 % | 25 % | 25 % | 1.0 % |
| 2.1.5 | Pump Speed 1 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.6 | Pump Compensation 1 | 1 % (0 disables) | 200 % | 200 % | 1.0 % |
| 2.1.7 | Pump Speed 2 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.8 | Pump Compensation 2 | 1 % (0 disables) | 200 % | 200 % | 1.0 % |
| 2.1.9 | Pump Speed 3 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.10 | Pump Compensation 3 | 1 % (0 disables) | 200 % | 200 % | 1.0 % |
| 2.1.11 | Pump Speed 4 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.12 | Pump Compensation 4 | 1 % (0 disables) | 200 % | 200 % | 1.0 % |
| 2.1.13 | Pump Speed 5 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.14 | Speed 5 (Priority/Additive) | priority | additive | additive | - |
| 2.1.15 | Pump Speed 6 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.16 | Speed 6 (Priority/Additive) | priority | additive | additive | - |
| 2.1.17 | Pump Speed 7 | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.18 | Speed 7 (Priority/Additive) | priority | additive | additive | - |
| 2.1.19 | Power Steer Speed | 0 % | 100 % | 100 % | 1.0 % |
| 2.1.20 | Power Steer Compensation | 1 % (0 disables) | 200 % | 200 % | 1.0 % |
| 2.1.21 | Power Steer Ramp Up Delay | 0.1 s | 5.0 s | 5.0 s | 0.1 s |
| 2.1.22 | Power Steer Ramp Down Delay | 0.1 s | 0.5 s | 0.5 s | 0.1 s |
| 2.1.23 | Accelerator Zero Level | 0.0 V | 5.5 V | 5.5 V | 0.02 V |
| 2.1.24 | Accelerator Full Level | 0.0 V | 5.5 V | 5.5 V | 0.02 V |

### 7.2.2 Pump Status Information

| Cal.Ref | Parameter Displayed | Min. Display (all units) | Max.Display (all units) | Step size (all units) | Log Info. |
|---|---|---|---|---|---|
| 2.2.1 | Battery Voltage | 0 V | 127 V | 0.1 V | + |
| 2.2.2 | Pump Motor Voltage | 0 V | 127 V | 0.5 V | |
| 2.2.3 | Pump Motor Current | 0 A | 1200 A | 6 A | + |
| 2.2.4 | Pump Controller Temp. | -30 °C | +225 °C | 1 °C | + - |
| 2.2.5 | Pump Mosfet Voltage | 0 V | 127 V | 0.5 V | |
| 2.2.6 | Capacitor Voltage | 0 V | 127 V | 0.5 V | |
| 2.2.7 | Key Switch Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hr (6min) | |
| 2.2.8 | Pump Pulsing Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hr (6min) | |
| 2.2.9 | Work Hours Count | 0 Hrs | 65279.9 Hrs | 0.1 Hr (6min) | |

Note : Log Info shows where the + and - keys can be used to access the service max and min data.

### 7.2.3 Pump Test Information

| Cal.Ref. | Input Displayed | Min.Display (all units) | Max.Display (all units) | Step size (all units) |
|---|---|---|---|---|
| 2.3.1 | Accelerator % Range | 0 % | 100 % | 1 % |
| 2.3.2 | Accelerator Voltage Range | 0.0 V | 5.7 V | 0.1 V |
| 2.3.3 | Pump Switch 1 | Open | Closed | - |
| 2.3.4 | Pump Switch 2 | Open | Closed | - |
| 2.3.5 | Pump Switch 3 | Open | Closed | - |
| 2.3.6 | Pump Switch 4 | Open | Closed | - |
| 2.3.7 | Pump Switch 5 | Open | Closed | - |
| 2.3.8 | Pump Switch 6 | Open | Closed | - |
| 2.3.9 | Pump Switch 7 | Open | Closed | - |
| 2.3.10 | Pump Inhibit Switch | Open | Closed | - |
| 2.3.11 | Seat | Open | Closed | - |
| 2.3.12 | Software Version/Revision | 000.00 | 999.99 | - |
| 2.3.13 | Controller Serial Number | 00000000 | 99999999 | - |

### 7.2.4 Pump BDI (as Traction 7.1.4, but only present in standalone Pump units)

### 7.2.5 Pump Fault Log (as Traction 7.1.5, but only present in standalone Pump units)

### 7.2.6 Pump Setup Menu Enables/Disables features

| Cal.Ref. | Feature | Options |
|---|---|---|
| 2.6.1 | Contactor Chopping | 24 V / On / Off |
| 2.6.2 | BDI | On/Off |
| 2.6.3 | Power Steer Trigger | None to FS1+Dir+Brake+Seat |
| 2.6.4 | Seat Switch Cuts Pump | On / Off |
| 2.6.5 | Fault Log | On / Off |
| 2.6.6 | Service Log | On / Off |
| 2.6.7 | Node Number | 0 to 15 |
| 2.6.8 | Only Cut PS1 | On / Off |

Note: changes only take effect after a key-switch recycle.

### 7.3.1 Traction and Pump adjustment descriptions

| Adjustment | | Description (T=Affects traction, P=Affects Pump) |
|---|---|---|
| Current Limit | T+P | Maximum allowable motor current. |
| Acceleration Delay | T+P | Time taken to ramp up from 0 to 100% on. |
| Deceleration delay | T+P | Time taken to ramp down from 100% to 0% on. |
| Creep Speed | T+P | Minimum applied % on when drive first selected. Only PS1 on pump |
| Maximum Speed | T | Maximum allowable % on. |
| Cutback Speeds 1&2 | T | Maximum allowable % on when cutback switches active. |
| Accel. Delay 1&2 | T | Independently adjustable acceleration delays during speed cutbacks. |
| Dir. Brake Current | T | Maximum braking current during direction switch change. |
| Footbrake Current | T | Maximum braking current in neutral when F.brake switch active. |
| Neut. Brake Current | T | Maximum braking current in neutral. |
| Bypass Over Current | T | Maximum allowable current in Bypass before contactor opens. |
| F.W. Pull In Current | T | F.Weak. contactor allowed to pull in at currents < pull in level. |
| F.W Drop out Current | T | F.Weak. contactor will drop out at currents > drop out level. |
| Power Steer Delay | T | Delay after power steer trigger removed until contactor opens. |
| Seat Switch Delay | T | Delay after seat switch opens until pulsing is inhibited. |
| Regen Time | T | Used to minimise delays for unsuccessful regen attempts at lowspeeds. Higher numbers give regen at lower speeds. 0 forces plugging only. |
| Brake Factor | T | Multiplication factor used to scale regen currents into end plug currents to improve regen to plug transition. E.g. Regen direction brake current =100A, Brake Factor=0.8, Plug current at end of braking cycle=80A |
| Zero Levels | T+P | Used to select minimum voltage input level for function. E.g. an Accel Zero level=0.5V means traction pulsing begins at 0.5V I/P |
| Full Levels | T+P | Used to select maximum voltage input level for function, E.g. an Accel Full Level of 4.0v means 100% pulsing is reached at 4V I/P |
| Speed Limit | T | Used with external speed sensor to provide speed limit feature. |
| D.Motor Inner Angle | T | Sets start of inner motor cut band. Typically 45° for non-proportional systems and 10 ° for proportional systems. |
| D.Motor Outer Angle | T | Sets start of inner motor reverse band. Typically 75° for non-proportional systems and ( 90 - $\tan^{-1}$( track / ( 2.wheelbase ) ) ) ° for proportional systems. |
| D.Motor Inner Ramp | T | Time taken to ramp up pulsing after inner motor drop out on any Dual Motor Non Proportional system |
| D.Motor Outer Ramp | T | As above, except ramp up time after inner motor reversal. |
| Inch Speed | T | Maximum allowable % on during inching operation. |
| Burst Inch Delay | T | Timer to allow inching for a set period only. |
| Bypass delay | T | Time for Bypass contactor to close after 100% on reached |
| Pump speeds 1-7 | P | Maximum allowable % on's when respective switch active |
| Power Steer Speed | P | As above, but for Power Steer speed. |
| Pump Comp. 1-4 | P | Set-up compensation by adjusting the relevant pump speed to give the required minimum no load speed, then set the associated compensation adjustment to give the same speed under full load conditions |
| Power Steer Comp. | P | As above but for Power Steer speed compensation. |
| Power Steer Ramp up | P | Independent acceleration delay for power steer function. |
| P. Steer Ramp down | P | As above but deceleration delay. |
| Speed 5-7 Priority/Additive | P | Lower numbers have priority over higher numbers. Additive is where the speeds 5-7 are added to lower numbered switches. |

### 7.3.2 BDI adjustment descriptions

| BDI Adjustment | | Description |
|---|---|---|
| Charge remaining | | Displays the remaining battery charge. This is a display only, no adjustments can be made. |
| Battery Voltage | | Adjustment used to enter the nominal battery voltage |
| Reset Volts/Cell | | Sets the voltage at which the BDI resets to 100% at power up. E.g. the BDI will reset to 100% on a 48V system, with the reset adjustment set to 2.20 Volts per cell, if the battery voltage is above 52.8V. (48V/2)*2.20V |
| Empty Volts/Cell | | Sets the voltage at which the BDI indicates the battery is fully discharged E.g. the BDI will eventually show 0% on a 48V system, with the empty adjustment set to 1.60 Volts per cell, if the battery voltage is below 38.4V. (48V/2)*1.60V |
| Warning Level % | | Sets the discharged level at which the warning threshold is reached, at which point the remaining lit segments flash. |
| Cutout Level % | | Sets the discharged level at which the cut-out threshold is reached, at which point all the segments flash together and the cutout action, Pump cutout and Traction speed 2 limit initiated. |

### 7.3.3 Setup Menu Descriptions

| Setup menu Option | | Description |
|---|---|---|
| Contactor Chopping | T&P | **24V/On/Off** - Set to **24V** to obtain 24V across coils when a lamp is also being driven, **On** when just contactor coils are being driven and **Off** when battery voltage contactor coils are used. |
| Accelerator type | T | **Linear/Curved/2*slope/Crawl** - Set to **Linear** for a straight line accelerator characteristic, Curved for more low speed manoeuvrability, **2*Slope** for a balance between Linear and Curved, and **Crawl** for a very shallow low speed manoeuvrability curve. See graph 2 appendix. |
| BDI | T&P | **On/Off - On** enables the BDI (Battery Discharge Indicator) and any warning/cutout settings, **Off** disables the BDI feature and removes the BDI setup menu display. |
| Power Steer Trigger | T&P | **None/FS1/Dir/F+D/Brake/F+B/D+B/F+D+B/Seat/F+S/D+S/F+D+S/B+S/ F+B+S/D+B+S/F+D+B+S/Pulsing** - These are the various triggers for power steer activation, **FS1 or F** = FS1 switch, **Dir or D** = Direction switch, **Brake or B** = Foot brake switch and **Seat or S** = Seat switch, e.g. setting to FS1 will trigger the power steer delay only when FS1 is closed, whilst setting to F+D+B will trigger the delay when either FS1 or Direction or the Brake switches are closed. Pulsing activates the power steer when traction **or** pump is pulsing. |
| Economy cuts traction current | T | **On/Off** - set to **On** for current limit to be reduced during economy or **Off** for just the standard acceleration delay increase. |
| Bypass in current limit | T | **On/Off - On** = Bypass at max %on and current limit, **Off** = just Bypass at max %on. |
| SRO | T | **On/Off - On** = SRO enabled, **Off** = SRO disabled |
| Braking | T | **Prop/Const - Prop** = Direction braking level is proportional to accelerator position, **Const** = Direction braking is constant level. |
| Seat switch cuts pump | P | **On/Off - On** = Seat switch cuts Traction and Pump, **Off** = just Trac. |
| Fault Log | T&P | **On/Off - On** = Fault Log enabled, **Off** = Disabled and no display. |
| Service Log | T&P | **On/Off - On** = Service Log enabled, **Off** = Disabled and no display. |
| Node Number | | **0-15** - Normally set to 0. With a multi controller CAN bus system set one controller to 0 to be the master for controlling the display and set the other controllers **1,2,3.....15.** |
| Only Cut PS1 | P | **On/Off - On =** BDI cutout only inhibits PS1, **Off =** BDI cutout inhibits PS1 to PS7. |
| Cut2 Lmt Spd | T | **On/Off - On =** Speed Limit is only active when Speed Cutback2 is active. **Off =** Speed Limit is active at all times. Note Speed limit is totally disabled if Speed Limit is set to 0 KPH. |

# 8 DIAGNOSTICS

## Traction and Pump Fault Messages and LED status/number of flashes

| | Calibrator Message | Standard Display | Full Feature Display | Led | Description and how to clear | Check... |
|---|---|---|---|---|---|---|
| 0 | OK (lowest priority) | | | on | Traction operational and OK. | No action required. |
| 1 | Testing... | Run Tests | | on | Only displayed briefly at power up. | No action required. |
| 2 | BDI Cutout | BDI Cut | BDI CUT OUT | 7F | BDI enabled and cutout action initiated. | Battery charged. |
| 3 | Thermal Cutback | Over Temp. | TRAC HOT | 8F | Traction heatsink above 75°C. Allow controller to cool. | Heatsinking, Mounting, Surfaces clean, fan req. |
| 4 | Speed Probe | Speed Probe | SPEED PROBE | 6F | Speed limit feature enabled & wire off. | Probe connections. |
| 5 | Accel. Fault | Accel Fault | ACCEL FAULT | 6F | Accel. pedal pressed at power up, or wire off. Recycle FS1 and Direction. | Accel wiring. Accel Zero & Full Personalities. |
| 6 | Contactor o/c | Cont o/c | CONTACT FAULT | 4F | Contactor has bad contact or didn't close, motor o/c. Recycle FS1 & Dir. | Coil wiring, power wiring, motor o/c. |
| 7 | Contactor s/c | Cont s/c | CONTACT FAULT | 4F | Contactor didn't open or is welded. Recycle FS1 and Direction switch. | Welded tips, particles in tips, wiring. |
| 8 | Steer Pot Fault | Steer Fault | STEER FAULT | 6F | Wire off steer pot input. | Steer pot wiring |
| 9 | Sequence Fault | Seq. Fault | SEQ FAULT | 2F | Direction or FS1 switch at power up. Recycle Direction FS1 or both. | Dir and FS1 in neutral and Dir/FS1 wiring. |
| 10 | 2 Dir. Fault | 2 Dir Fault | 2 DIR FAULT | 2F | Two directions selected together. Recycle both Directions and FS1. | Direction switch wiring. |
| 11 | SRO Fault | SRO Fault | SRO FAULT | 2F | Dir. switch selected > 2 secs after FS1. Recycle FS1 and Dir. | Dir first then FS1, FS1 and Dir. switch wiring. |
| 12 | Seat Fault | Seat Fault | SEAT FAULT | 2F | Drive selected and no seat sw. Recycle Dir and FS1 switch | Seat switch, closed, seat wiring. |
| 13 | Inch Fault | Inch Fault | INCH FAULT | 2F | Inch switch at power up , both inch switches selected or inching attempted with seat switch or Dir/FS1 selected. Recycle inch switches. | Inch switch in neutral at power up, only 1 selected, Seat/Dir/FS1 switches open. |
| 14 | Steer Fault | Steer Fault | STEER FAULT | 2F | Outer switch closing before inner. | Switch operation/wiring. |
| 15 | Battery Low | Bat. Low | BATTERY LOW | 7F | Battery < Low battery personality. Recycle FS1 or Direction switch | Correct battery voltage, Discharged battery. |
| 16 | Battery High | Bat. High | BATTERY HIGH | 7F | Battery > High battery personality. Recycle FS1 or Direction switch | Correct battery voltage. Loose or missing B+ to controller. |
| 17 | Pers Error | Pers Error | PERS ERROR | 1F | Personalities out of range at power up. | Reset personalities out of range (shown as ----.-). |
| 18 | CRC error | CRC Error | CRC ERROR | 1F | One or more personalities have been corrupted. | Check **all** personalities then recyclekKeyswitch. |
| 19 | Coil s/c | Coil s/c | COIL FAIL | 9F | A contactor coil s/c or miswired. Recycle Keyswitch | coil s/c, Drive connected directly to B+ve, wiring. |
| 20 | Mosfet s/c | FET s/c | MOSFET FAIL | 3F | Bypass contactor s/c or Mosfet s/c Recycle FS1 or Direction | F1/F2 /B- power wiring, Mosfets s/c. |
| 21 | Various internal controller power up messages (highest priority) | FAIL | FAIL | off | If any of these message are displayed then the controller has failed one of its internal power up checks. | Contact Sevcon. |

# 9 SERVICE AND FAULT LOGS

The Service and Fault Logs have been incorporated to allow end users and service personnel to inspect and note the controller's performance and fault history. Utilising the controller's existing Status measurements and Diagnostics capabilities, information (such as the maximum temperature the controller has operated at or the number and type of faults that have been detected) can be stored in non-volatile memory and presented at a later date. Both the Service and Fault logs can be selected/deselected via the setup menu on the calibrator, and when selected can be cleared at any time to start recording new data.

## 9.1 Service Log

Service information is available in the Traction and Pump Status menus, where holding down the '+' key shows the maximum value of the current item, and holding down the '-' key shows the minimum value. The following items are logged:

- Maximum Battery Voltage
- Maximum Motor Current
- Maximum Controller Temperature and Minimum Controller Temperature.

To clear the log, access the "Service Log + to reset log" message at the end of the Status menu, and follow the prompts. The service log can be enabled and disabled in the Setup menu.

## 9.2 Fault Log

The Fault log is available at location 1.5 on the calibrator. Faults are grouped together by "LED flash fault"; the types of flash fault and whether each is logged is shown below. Generally faults that can occur during normal operation, e.g. a 2 flash driver procedure error or an 8 flash thermal cutback indication, are not logged.

| | | |
|---|---|---|
| - LED off faults | Logged | (Internal controller power up check faults) |
| - 1 flash faults | Logged | (Personality/CRC faults) |
| - 2 flash faults | Not Logged | (Driver procedure/sequence/wiring type faults) |
| - 3 flash faults | Logged | (Mosfet/Bypass wiring type faults) |
| - 4 flash faults | Logged | (Contactor o/c or s/c or wiring type faults) |
| - 5 flash faults | Not Logged | (Not used) |
| - 6 flash faults | Logged | (Potentiometer wire off type faults) |
| - 7 flash faults | Logged | (Battery low or high faults) |
| - 8 flash faults | Not Logged | (Thermal cutback faults) |
| - 9 flash faults | Logged | (Contactor coil s/c type faults) |

Each of the above logged categories contains - The total number of faults of this type, the Key hours count of the most recent fault and a text description of the fault. An example of how the Fault Log information is presented is shown below:

| |
|---|
| 12*04F 12345.6hr<br>Contactor o/c |

This display shows that 12 4-Flash faults have occurred and been logged, the most recent at 12345.6 Key hours and it was a Contactor o/c fault.

Once into the fault log menu, the left and right arrows are used to view any faults stored and at the end of the list a "Fault Log + to reset log" message is shown, where the Fault Log can be reset in a similar way to the service log. The Fault Log can be enabled and disabled in the setup menu.

# 10 CONTROLLER OPERATION AND FEATURE DESCRIPTIONS

## 10.1 TRACTION OPERATION

10.1.1 **Start Up Sequence** - At key switch on, the Direction and FS1 switches must be in the neutral condition simultaneously at least once before drive can be selected. This is a safety feature to help prevent unexpected movement immediately after power up. This Start up Sequence can be removed as an option but this is not recommended.

10.1.2 **SRO** (Static return to off)- This feature is optional in the setup menu and when specified, forces the following sequences of switch inputs to be followed before drive is allowed: Keyswitch-Direction-FS1 or Keyswitch-FS1-Direction (within 2 seconds of FS1). Any other sequence will not allow drive. Drive will be inhibited if FS1 is active for more than 2 seconds with no direction selected. In this case the FS1 will need to be recycled.

10.1.3 **Seat Switch** - If the seat switch is opened and the seat switch timer has timed out during drive the controller will stop pulsing and a seat fault will be indicated. Before drive can be restarted the seat switch must be closed, and FS1 and the direction switch must be recycled through neutral. Note the start sequence for drive requires that the seat switch is closed and both the direction and FS1 switches are in the neutral position simultaneously before drive can be initiated. The time period is programmed by means of the Calibrator (Seat Switch Delay). As a setup menu option the seat switch can also inhibit pump operation if required. There are also additional seat switch start up sequences available as options, although the above described SEVCON standard is recommended.

10.1.4 **Handbrake Switch** - An input is provided for the connection of a handbrake switch, which if operated will disable traction pulsing but leave the drive related contactors in position to effect a minimum roll back hill start when drive is selected and the handbrake is released.

10.1.5 **Acceleration Delay** - This is an adjustable delay and sets the time taken to ramp up from 0 to 100% on full drive demand.

10.1.6 **Deceleration Delay** - This is an adjustable delay to ramp down the pulsing from 100% on to 0% on, and can be used to limit the inherent truck lurch when acceleration is interrupted. When neutral is selected, contactors are only opened when the % on has ramped down to 0.

10.1.7 **Creep** - The Creep speed is adjustable and is used to select a minimum pulsing level as soon as drive is requested, to minimise delays and dead bands. The motor voltage is rapidly ramped to the creep level (equivalent to a 100mS acceleration delay).

10.1.8 **Cutback speeds** - There are 2 cutback switch inputs. Each one has an associated personality to adjust the maximum % on when the switch is active. In addition each cutback has an independently adjustable acceleration delay associated with it to further enhance low speed manoeuvrability. When both switches are active together, the lower speed is selected together with the slowest acceleration delay. The cutback speed inputs are usually normally closed so that a wire off type fault or bad connection initiates a lower speed.

When the BDI feature is enabled and the cut out level is reached the speed 2 cutback is automatically initiated.

A maximum speed adjustment is also available to limit the maximum applied %on. (If the setting is less than 95% then Bypass and Field Weakening are disabled).

10.1.9 **Bypass** - The Bypass contactor is used to short out the main Mosfet switching device to increase speed and efficiency at high speeds and to allow higher motor currents than the controller's maximum current limit, to climb ramps laden or to escape from ruts or pot holes.

**Bypass can be initiated in 2 ways:**

**Current-limit Bypass**: the accelerator is fully depressed and the controller has been in current limit for longer than 2 seconds. In order to prevent a sudden lurch of the truck the contactor will not be energised if the motor voltage during current limit is less than 20% of battery voltage. This mode of operation can be disabled via the setup menu.

**High-speed Bypass:** If the accelerator is fully depressed and the controller has been pulsing at maximum % on for 1.5 seconds and the Bypass Delay personality has timed out. The Bypass delay timer is a feature that can be used to allow the truck to obtain full speed, before contactor closure.

The bypass contactor will be de-energised if the accelerator demand is reduced below 86%, or if the motor current exceeds the Bypass over-current dropout level, adjustable by the calibrator. To allow for initial overshoots the over current test is disabled for the first 2 seconds of Bypass. Although the software attempts to minimise arcing when the contactor opens, some arcing is inevitable under certain load conditions. After an over-current drop out, the Bypass function will be inhibited until neutral is recycled to prevent repeated opening and closing of the tips under heavy current conditions.

Bypass can be disabled by setting the over-current drop out to 0 A. Also Bypass will be disabled if either of the 2 speed cutback switches are enabled and the settings are adjusted below 95% or the maximum speed setting is less than 95%. Applying the footbrake switch or economy > 0% will also prevent Bypass closure.

10.1.10 **Field Weakening** - This is carried out by connecting a low value/high wattage resistor connected in series with a contactor across the traction motor field to weaken the field and hence increase speed whilst reducing torque. As a guide line the value of the resistor should be the same as the motor field resistance and it should be rated to carry field current.

At full accelerator depression and maximum %on, and after bypass contactor closure (if fitted) the field weakening contactor is energised providing the current is below the Pull-In level. If the motor current increases above the Drop-out level or the accelerator demand is less than 86% or the bypass contactor is de-energised, the Field Weakening contactor will be opened. Both the Field Weakening Drop-Out and Pull-In current levels are adjusted with the calibrator.

10.1.11 **Power Steer** - A contactor drive is available to control a separate Power Steer motor. An adjustable delay allows the motor to operate for a set time, after the power steer trigger or power steer demand has been removed. SEVCON'S standard trigger, i.e. when the contactor is closed, is when either FS1 or the Footbrake switch is closed, or the Traction unit is pulsing. It is an either-or situation, so any one of these 3 inputs is sufficient to trigger the Power Steer.

This standard trigger is designed to give power steer when ever the truck is moving, but not to have a situation where the Power steer could be on continuously, i.e. on a direction switch where the truck could be left with a direction selected and the Key switch left on. If FS1 or the Footbrake is applied then the vehicle is either about to move or is moving, and the Traction pulsing is used if the truck was neutral braking (pulsing) down a long ramp, when it is conceivable that neither of the two switches would be closed. On a tow-tractor, power steer is disabled during inching.

An independent input pin (connector A, pin 14) also exists to trigger Power Steer operation. This is normally used in conjunction with a steer on demand system where an output is generated when the steering wheel is turned. This gives Power steer on demand and is more efficient since typically no steering delay, or only a short delay is needed.

The independent trigger only, or other trigger combinations can be configured if necessary in the setup menu. Some vehicles derive the power steering assistance from the main Pump Hydraulic motor, instead of having a separate Steer motor. In this situation the trigger is fed to the Pump controller and runs the pump at the speed set by the P. S. Speed personality 2.1.19.
Independent ramp up and ramp down delays are provided when Power steer assistance is derived from the main Pump controller, to help tune steering responsiveness without affecting the main pump operation.

10.1.12 **Regen Braking** - Regen provides vehicle braking by controlling the motor as a generator and returning the generated energy back to the battery. Regen braking reduces motor heat dissipation compared with plug braking. Regenerative braking can be initiated in 3 ways, each with an independently settable braking level, as follows:

i) A direction switch change will initiate regen braking at a level set by the Direction Brake Current level. Braking effort is proportional to the accelerator position, with a minimum accelerator pedal position giving 50% of the set brake level increasing to 100% for a fully depressed pedal. The proportionality range allows the driver to modify the braking effort without allowing freewheeling. The proportionality feature is optional and can be configured in the setup menu to give fixed braking at the set personality level.

ii) Closure of the foot-brake switch in neutral, will initiate regen braking at the Footbrake personality level. An input is provided to allow braking effort to be proportional to the Footbrake position if a potentiometer is fitted. Setting a 0 into the personality disables braking on the Footbrake switch.

iii) When neutral (i.e. there is no direction selected or FS1 is opened) is selected, regen is initiated at the Neutral Brake Current level. Setting a 0 into the personality disables neutral braking and allows freewheeling. Neutral braking will only be attempted if the % on in the previous direction exceeded 20% above the set creep level. This helps minimise unnecessary delays and contactor operations.

Regen braking is some times not possible at low speeds depending on the motor characteristics. To help minimise delays attempting to regen, a Regen Time adjustment is offered which can be set so that Regen is only attempted for a short period of time, which is sufficient to initiate regen at medium to high speeds but not to cause unnecessarily long delays at very slow speeds where regen is not possible. If the Regen Time setting is increased then regen can be initiated at lower speeds. Setting the Regen Time to 0 disables regen and forces plug braking only.

If regen is not possible due to low vehicle speed, the following action will be taken:

1) For direction braking, plugging will be used to slow, then reverse the vehicle.
2) For neutral or footbrake braking, the vehicle will freewheel.

The switching frequency in Regen is high frequency and silent.

10.1.13 **Plug Braking** - Plug braking is achieved by controlling the rotating motor armature as a generator and dissipating most of the energy in the motor and the plug diode.

For plugging-only controllers, the conditions for initiating braking are identical to those for regen controllers: on a direction change, footbrake switch and in neutral. Plugging also operates on regen controllers if the truck has been travelling too slowly to initiate regen direction braking.

The switching frequency in the Plug braking mode is high frequency and silent.

10.1.14 **Brake Constant Factor** - This adjustment has been added to match braking levels between Regen and Plug braking.

The plugging current on regen controllers is equal to the direction change regen current multiplied by the constant factor. For example, if direction change regen in neutral is operating at 100A, a factor of 0.8 would give 80A of Plug braking when regen was not possible due to low vehicle speed.

This adjustment is not necessary on plugging-only applications as the 3 braking adjustments are now dedicated to plug braking levels.

10.1.15 **Inching** - This facility is normally used on Tow Tractors to manoeuvre the Tractor towards the load from the rear of the vehicle, using 2 inching buttons, one for forward and one for reverse. The inch speed is adjustable via the calibrator.

Inching will only operate if the main direction control and FS1 switches are in the neutral position and the seat switch is open, and handbrake off. These safety interlocks prevent anyone from sitting in the driver's cab whilst an operator is using the inching switches at the rear.

A burst inching feature is also available which uses inching in conjunction with an adjustable timer to provide inching for a limited period. This is typically used in conjunction with an electromechanical brake to provide inching on gradients and to help prevent against unlimited travel if an inching button became jammed in the closed position or failed short circuit.

10.1.16 **Anti-Rollback** - This is a standard SEVCON feature and is used to help prevent roll back conditions on ramps. If the driver reselects the previous direction after a neutral condition, braking is not attempted, and full drive power is available to restart on a hill. This feature minimises the delay after selecting drive before pulsing starts, thus limiting the distance the vehicle will roll before the motors are able to drive.

10.1.17 **Analogue Inputs** - The Traction accelerator input, as well as the other 3 analogue inputs are very flexible in the range of signal sources they can accommodate and can be adjusted to minimise deadbands and mechanical tolerances. Each of the 4 analogue inputs has 2 adjustments associated with it, that allow the input voltage range to be determined.

For the Traction Accelerator, for example, the 2 adjustments are called the "Accelerator Zero Level" and the "Accelerator Full Level". If these were set to 0.20V and 4.80V then 0% pulsing would start at 0.20V at the input, increasing to 100% pulsing at 4.80V. For accelerators with decreasing voltage outputs, the Zero adjustment might be set to 3.5V and the Full adjustment to 0.0V. The Calibrator test menu shows the instantaneous voltage reading, and the equivalent % "push" for each input, and to allow easy set-up, pressing the "down" key on the calibrator from either of these test displays, allows a direct jump to the Zero voltage and Full voltage personality settings. Note that a 6 flash fault will occur if the full and zero levels are set within 0.50V of each other.

For details of the 3 wiring options, see section 5.3.8., and for an example of each method see Figure 1.

10.1.18 **Traction Accelerator** - When Drive is selected and the accelerator is first pressed, pulsing will commence at the Creep Speed setting increasing towards the maximum %on.

If the accelerator is depressed at power up, pulsing will be inhibited and a 6 flash fault will be indicated, until the pedal is released. In case of a wire off type fault, pulsing will be limited to the creep setting and a 6 flash fault will also be given.

Various accelerator characteristics i.e. relationship between accelerator push and the applied motor voltage, can be selected via the setup menu. There are 4 options: Linear, Curved, 2*slope and Crawl. Set to Linear for a straight line accelerator characteristic, Curved for more low speed manoeuvrability, 2*Slope for a balance between Linear and Curved, and Crawl for a very shallow low speed manoeuvrability curve. See graph 2 for actual characteristics.

10.1.19 **Footbrake Potentiometer** - This input is available to allow a potentiometer to be fitted to the Footbrake pedal for proportional braking. It can be connected and set-up as per the accelerator input. Alternatively a switch can be used to give a on/off operation. Note that footbrake operation drops out both Bypass and Field weakening.

10.1.20 **Economy Potentiometer** - This potentiometer, normally available to the driver of the truck, varies the acceleration ramp delay from its set value to its maximum value. It can be adjusted as per the accelerator input. As a setup menu option the economy function can reduce the traction current limit, instead of increasing the acceleration delay. See graph 2 appendix for characteristic. Note that the economy function drops out both Bypass and Field Weakening.

10.1.21 **Steering Potentiometer** - For Dual Motor traction applications, the footbrake input can be reassigned to be a steering potentiometer input.

10.1.22 **Digital Switch Inputs** - The digital inputs on the controller can be configured as Active Low inputs, where the switches are wired to B-ve, or as Active High inputs where the switches are connected to B+ve. The SEVCON standard is Active Low, and is recommended for it's low impedance input stage and immunity to moisture related problems. Active High inputs are a hardware option which must be specified when the controller is manufactured.

In addition a further configuration allows each input to be specified as normally open or normally closed. Most switches are normally open, with the exception of the 2 speed cutback switch inputs which are normally closed, so that a wire off type fault, or bad connection initiates the cutback speed, rather than a higher speed. On compensated Pump systems the Power Steer input can be conveniently configured as normally closed.

10.1.23 **Contactors** - There are up to 8 outputs for driving contactors as described in previous sections. It is also possible to reconfigure one of the outputs, normally contactor drive 8, as an external LED or Lamp driver to allow dashboard indication of the controller's integral LED.

The controller can diagnose open circuit (o/c) and short circuit (s/c) problems with certain contactors, as described in the diagnostic section. Generally, following a request to open a contactor, the controller will report a 4 flash fault and a calibrator message if a successful operation was not detected after approximately 500ms. To help prevent against minor tip contaminants causing spurious diagnostic trips when closing a contactor, if a closure is not detected after 500ms, pulsing up to a maximum of 25% is allowed. This is designed to pass a controlled amount of current to try and break through any contaminant present to allow uninterrupted drive. If a closure isn't detected on reaching 25%, then the contactor drive is removed and a 4 flash fault is indicated.

An optional Line Contactor can be connected between the B+ terminal of the controller and battery positive to help prevent large currents flowing through the battery connectors and into the internal capacitors when the controller is first connected to the battery. After the keyswitch has been switched, and once the capacitors have charged up (via internal resistance) the line contactor will be energised. An internal diode fitted in the keyswitch line will prevent any contactor energising if the polarity of the battery voltage is reversed. On Pump controllers the Line Contactor also gives a mechanical break.

Under normal operating conditions contactors will operate without arcing. However, under certain fault conditions, contactors may arc when opening. The Bypass contactor may also arc during Bypass over-current drop out conditions.

10.1.24 **Contactor chopping** - This feature allows 24 V contactors to be used at all battery voltages 24V - 96V, by continuously monitoring the battery voltage and chopping the contactor output pins accordingly, to present an average voltage suitable for 24V coils. Chopping is selectable by the calibrator. All the contactor drives will be either chopped or not chopped. It is not possible to select individual drives to chop. Care must be taken to ensure that chopping is always selected if 24V contactors are being used on battery voltages higher than 24V. In applications > 24 volts contactors must be fitted with blow out magnets.

Chopping can reduce the overall dissipation in the coils and allows only one set of contactors to be stocked for all battery voltages.

Chopping Frequency approx. = 650Hz (Slightly audible at higher battery voltages)
Typical contactor coil voltage during chopping = 16 volts.
Typical contactor coil voltage during energisation = 24 volts for 1 second.

There are 3 contactor chopping options available via the setup menu: Off, On and 24V. The off setting is used for nominal battery voltage coils, and the On setting is for 24V coils on higher voltage vehicles. Setting to 24V provides chopping for 24V coils and lamps without the drop to 16V after 1s.

### 10.1.25 Fail-safe

The controller's safety system includes a microprocessor watchdog which can detect software failure, and a hardware fail-safe system which can prevent dangerous runaway conditions in the event of certain hardware failures.

Every time the controller is powered-up, the software checks that the fail-safe circuit is able to switch off the Mosfets and open at least 2 contactors.

### 10.1.26 Dual Motor Operation - General Principles

The SC2000 can drive twin traction motor systems using either a single chopper (non-proportional control) or a twin chopper (proportional control). In both modes, 2 of the contactor drive outputs must be assigned as an additional set of direction contactors for the second motor. Depending on the steering angle, the inner motor of a turn can be reduced in speed, and then reversed (for 3-wheel vehicles). For increased safety, the overall speed of the vehicle can also be reduced as it turns.

The steering information can be provided by either 3 switch inputs (inner-left steer switch, inner-right steer switch and the outer switches connected in parallel) or a steer potentiometer. Sevcon recommends a steer pot., as this allows linear inner-wheel control on proportional systems, and linear speed cutback in turns on all vehicles. As the steering characteristics for a potentiometer can be adjusted via the calibrator (items 1.1.29 and 1.1.31), mechanical adjustment is not required. See section 7.3.1 for typical values. The inner angle and outer angles personalities must be at least 5° apart. If problems exist with setting the values, check the other setting to ensure it is not within 5 degrees.

For all dual motor systems, the steering range 0 - 90° is split into 3 sections: the dead-band, the cut-band and the reverse-band. The characteristics of each are shown below:

| Band | Definition for Steer Pot. | Definition for Steer Switches | Maximum Vehicle Speed | Inner Motor Speed | Inner Motor Direction | Bypass & Field Weakening |
|---|---|---|---|---|---|---|
| Dead Band e.g. 0° - 10° | steer angle is less than inner angle | all steer switches open | 100% | 100% | Same as direction lever | Enabled |
| Cut Band e.g. 10° - 70° | steer angle is between inner and outer angles | one inner switch is closed | reduced to cutback speed #1 | reduced to 0% | Same as direction lever (or stationary) | Disabled |
| Reverse Band e.g. 70° - 90° | steer angle is greater than outer angle | one inner and outer switch is closed | reduced to cutback speed #2 | increased to cutback speed #2 | Opposite of direction lever | Disabled |

### 10.1.27 Dual Motor Non-proportional - Additional Notes

Depending on how closely the motor characteristics are matched and whether circulating currents exist between the two motors during braking, a balancing contactor may be required (see Figs 5 & 7). The balance contactor is open when driving, and closed under all other normal conditions.

To minimise lurches during cornering the chopper is ramped-down using the standard acceleration delay prior to changing the direction of the inner wheel. Once the contactors have changed, the chopper is ramped up at one of two rates depending on the type of direction change: The inner ramp rate is used between the dead-band and the cut band, and the outer ramp rate is used between the cut band and the reverse band.

10.1.28 **Speed Limit** - A traction speed limit in KPH can be set via personality 1.1.28 (0 KPH disables the feature). As the speed of the vehicle approaches the limit, the maximum motor voltage is reduced. If the speed limit is exceeded by more than 2 KPH (when the vehicle is travelling down-hill for example) electrical braking will be used until the speed of the vehicle falls to below the limit. Speed limit braking may operate in normal drive (as described above), to increase existing braking torque if the vehicle over-speeds, or if the vehicle is rolling in neutral.

The actual limit speed of the vehicle is typically ± 2 KPH of the personality setting, depending on motor loading. When the feature is enabled, a probe "wire-off" feature will limit the motor voltage if the probe is disconnected.

Calibration of the feature is made via the set menu items "Full Speed" (1.6.13) and "Probe Frequency" (1.6.14). Full Speed should be set to the maximum speed of the vehicle, unloaded on level ground. The Probe Frequency setting should be the output frequency of the sensor **at that speed**.

The recommended sensor is an active low (i.e. NPN) inductive proximity switch. The output is connected to connector A, pin 13. A +12V supply on connector A, pin 24 can be used for most types of sensor. The negative supply of the sensor should be connected to the controller's B- terminal. Contact SEVCON for further recommendations if required.

The operation of the speed limit function can be disabled by setting personality 1.6.15 to ON. In this situation the speed cutback 2 switch is used to enable/disable the speed limit functionality. i.e. With speed cutback 2 not active then there is no speed limit, with speed cutback 2 active the speed is limited to the value set in 1.1.28.

## 10.2 PUMP OPERATION

10.2.1 **Pump Operation** - There is no start-up sequence so pulsing will be initiated after a small delay at power-up if one or more of the pump switches is selected. There are adjustable ramp up and ramp down delays. A Pump contactor can be specified as an option. There are facilities for prioritising pump speeds, for having different pump speeds added together and for having speed compensation for different load conditions.

10.2.2 **Pump Speeds and Priorities** - Each of the are 7 pump switch inputs has its own speed setting. The pump speeds are prioritised in numerical order so that Speed 1 has priority over all other speeds and Speed 2 has priority over Speeds 3 to 7, etc. Example:- If Speed 1 is set to 10%, Speed 2 to 20% and Speed 3 to 30% then selecting Speeds 1 and 3 will give 10% and selecting Speeds 2 and 3 will give 20%.

10.2.3 **Additive speeds** - There is also an additive feature available on pump switches 5,6 and 7 which is selected when the personality after the respective pump speed adjustment is set to "Additive". When this adjustment is set to "Priority" the pump speeds behave as described in 10.2.2.

The additive feature works by adding a speed selected by either pump switch 5,6 or 7 to another selected speed to give increased power to handle the simultaneous pump operations.

Example:- If speed 2 is set to 40% speed 5 is set to 25%, and speed 6 is set to 10%, then selecting all 3 switches will give a demand of 75%. whilst selecting only speeds 2 and 5 would give 65%.

10.2.4 **Pump accelerator input** - The pump accelerator demand is associated with Speed 1. The pump will operate at the Creep Speed setting when the accelerator is at minimum demand and change linearly to Speed 1 as the accelerator is increased to the maximum demand. The pump pot accelerator input can be connected and adjusted as per the previously described traction accelerator input.(9.1.18).

10.2.5 **Power Steer speed** - On compensated pump systems this setting can be used to control the power steer speed from the main pump motor. This speed is selected from the power steer trigger input as previously described and can be compensated for as described in the section below. The power steer also has independent ramp up and ramp down delays. See the section 9.1.11 on Power Steer for more information.

10.2.6 **Pump Inhibit Input** - This input can be used in conjunction with external equipment such as a separate BDI unit for example, to disable Pump operation when the battery is low. All Pump speeds are inhibited at the end of the operating cycle, except the Power Steer speed.

10.2.7 **Pump Speed Compensation** - Some trucks utilise the main hydraulic pump motor to provide power steering assistance, instead of a separate power steer motor. This feature provides speed compensation so that the pump motor always provides steering assistance, whilst allowing the motor to slow down when assistance isn't required to minimise noise and improve efficiency. Pump speeds 1 - 4 and the Power Steer speed can be compensated if required.

The compensation is a straight line characteristic set up using 2 personalities. The set up procedure may require some repetition to give optimum performance of low load (low noise) and full compensated load. The low load speed is normally set up to run the pump motor at its lowest permissible lubrication speed to keep audible noise to an absolute minimum.

The calibrator's base speed sets up the low load speed and the compensation factor sets the amount of boost when the controller detects a current increase due to the pump motor load increasing. The controller monitors the motor current and changes the motor voltage to ensure that the motor remains on this compensated speed line.

Set up Procedure - Set both the base speed and the compensation factor to 0. Activate the pump switch associated with the speed to be compensated. Ensure that the motor has its minimum load. Increase the Base speed until the correct operating speed at minimum load is achieved. Increase the load associated with this pump speed to its maximum. Increase the compensated speed until varying the load has little or no effect on the speed.

Example - Power steer compensation where the main pump motor provides the hydraulic steering assistance. Set the Power Steer personality base speed and compensation factor to 0. Activate the Power Steer Trigger input and increase the Power Steer base speed until the pump motor is running at its desired low speed. Operate the steering. Very little assistance will be given if the pump is going slow. Increase the Power Steer compensation setting until the required amount of assistance is given when the steering is operated. The set-up is an iterative process so it may be necessary to change the base speed again and repeat the procedure to obtain optimum results.

10.2.8 **Pump Bypass/F.Weak** - This contactor output will energise 1.0 second after the pump has reached full speed (100% on), and can be used to switch a contactor across the main Pump Mosfet device to act as a Bypass contactor, or it can switch a contactor with a series resistance to act as a Field weakening contactor.

10.2.9 Pump Contactor on Standalone Traction Units - On standalone Traction controllers a pump contactor can be fitted that is operational from any of the pump 2 -5 switches. Operating these switches on a standalone traction unit will also increment the pump hours count.

## 10.3 GENERAL OPERATION

### 10.3.1 Operating Frequency

The drive frequency of both the Traction and Pump power frames is 15.67Khz, for silent operation. For Traction plug and regen-braking the frequency is also 15.67Khz and silent.

### 10.3.2 Temperature Monitoring

If the temperature of either power frame exceeds 75$^{O}$C its maximum available current will be reduced. Note, however, that if the set current limit is less than the maximum available current limit actual cutback will occur at progressively higher temperatures than 75oC. The thermal cutback ensures that the maximum heatsink temperature is limited to 95$^{O}$C (See Graph 1). When actual cutback occurs the diagnostic LED will flash 8 times. Inspection of the calibrator fault messages will indicate which unit is in thermal cutback.

### 10.3.3 Safe Operating Area (SOA)

The controller's current may be limited at high and/or low duty cycles depending on its current and voltage specification. This is to reduce the thermal stress on the power components in order to increase long term reliability. See Graph 2.

The "Safe Operating Area" is a characteristic of the MOSFETs and Freewheel Diodes which make up the powerframe. The MOSFET SOA restricts current at high duty cycles on all configurations, and the Diode SOA tends to restrict the current at lower duty cycles on lower voltage applications.

For most applications SOA will have little or no effect on the operation of the controller. It's effect is more significant in protecting the controller against adverse loads such as damaged motors and static test rigs.

### 10.3.4 Under-voltage and over-voltage protection

In order to prevent a sudden loss in power, the controller will begin to linearly ramp down the current limit, once the average battery voltage falls below a pre-set under-voltage start level. The current will be ramped down to 0 and a 7 flash fault indicated if the averaged battery voltage falls below the under-voltage cut-out level.

To protect the controller from over-voltage caused by prolonged regen braking the regen current is cutback linearly from 100% when the average battery voltage reaches the over-voltage start level, to the minimum braking level at the over-voltage cut-out level.

If the battery voltage exceeds the over-voltage cutout level, all pulsing is stopped and a 7-flash fault is indicated. This protects against incorrect battery connection.

| Nominal Battery Voltage | Under-voltage Cutout | Under-Voltage Start | Over-voltage Start | Over-voltage Cutout |
|---|---|---|---|---|
| 24 V | 14.5 V | 18.0 V | 40.0 V | 45.0 V |
| 48 V | 14.5 V | 18.0 V | 65.0 V | 70.0 V |
| 80 V | 43.0 V | 60.0 V | 95.0 V | 100.0 V |
| 96 V | 43.0 V | 60.0 V | 120.0 V | 125.0 V |

### 10.3.5 **Diagnostic LED**

This is mounted between the connectors on the front of the controller. It serves as a simple diagnostic tool as explained below:

| | |
|---|---|
| Constant illumination | - No fault, normal condition |
| LED extinguished | - Internal controller fault |
| 1 flash | - Personality out of range |
| 2 flashes | - Illegal start condition or illegal steer switch inputs (Traction) |
| 3 flashes | - Mosfet Short Circuit |
| 4 flashes | - Contactor fault or Motor Open-Circuit |
| 5 flashes | - Not used |
| 6 flashes | - Accelerator, Steer Pot or Speed Probe wire off fault |
| 7 flashes | - Low or High battery voltage or BDI cutout operating |
| 8 flashes | - Over temperature |
| 9 flashes | - Contactor coil s/c |

Further explanation of the LED flashes are displayed on the calibrator fault message section.

### 10.3.6 **Fault Clearance**

Any fault indication will be cleared by re-initiating the start sequence after the cause of the fault has been removed.

### 10.3.7 **Software Version and Revision indication**

For identification purposes and to assist in queries, the Software version and revision, and the controller serial number are indicated in the calibrator Test Menu.

### 10.3.8 **Dashboard Displays**

Sevcon offers both a standard display and a full feature display for connection to the SC2000. See section 11 for more information.

### 10.3.9 **Setup Menu**

A setup menu has been added to the Calibrator that allows various features to be enabled and disabled. See section 7 for more information.

Note. Once a change has been made to the setup menu, the Key switch must be recycled for the change to be operational.

### 10.3.10 **Node Number**

Using the setup menu a facility exists to adjust the Node Number between 0 and 15, and is used to determine which Controller, on a multi controller CAN system, is the master and communicates with the display. On single Controller systems, including integrated Traction+Pump systems the number will always be set to 0. However on systems where there is more than one controller i.e. a standalone Traction controller and a standalone Pump controller, one of these should be set 0 and the other to 1. On Multi controller systems number the master 0 and the others 1,2,3...etc.

### 10.3.11 **Multi Languages**

Non-English languages can be specified for displaying on the Calibrator. Languages can be presently specified as either English, German, Spanish, Italian or French.

# 11 DASHBOARD DISPLAYS - OPERATION AND FEATURE DESCRIPTIONS

SEVCON offers 2 dashboard mounted CAN (Controller Area Network) Displays for any SEVCON controller equipped with serial CAN communications, including the SC2000 range. A standard display offers a compact design compatible with 2" dashboard hole mounting, and a full-feature display offers a higher specification LCD. Both are back-lit for use in low ambient light conditions.

Both displays have BDI Indication and 4 hours-counters. The hours counters are retained in the display in the event of the controller or the controller's logic being replaced in the field.

## 11.1 STANDARD DISPLAY

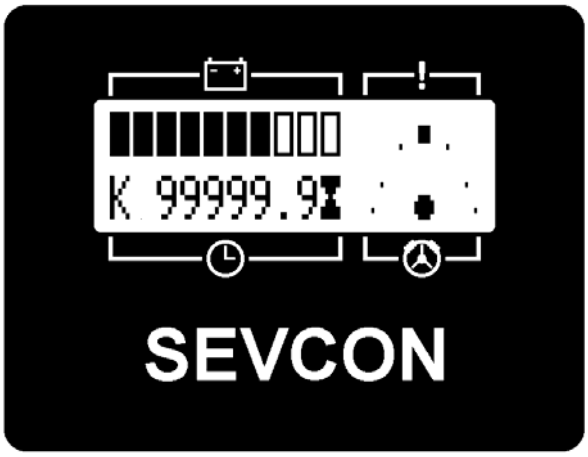
The unit consists of a 2x16 alphanumeric LCD display housed in a standard 50mm circular plastic case, with a rectangular front facia. The display incorporates a 10 segment BDI (Battery Discharge Indicator), a 6 digit hours counter and a 10 character area for diagnostic and status messages. When there are no diagnostic messages the area can be used to indicate a variety of system status readings, including Steer Angle.

### 11.1.1 STANDARD DISPLAY FEATURES.

- One unit for 24V-96V.
  * Standard 50mm circular case with rectangular front facia, enclosed to IP65
  * Alphanumeric display 2x16 characters.
  * Readily understandable display format consisting of numbers, text and segments.
  * 10 segment BDI indication, with low charge warning and cut-out warnings.
  * 10 character text based diagnostic/status display.
  * 6 digit hours counter with 0.1 hour indication, and flashing "egg timer" counting symbol.
  * Capable of counting up to 99999.9 hours. Equates to 34 years @ 8 hour shift per day
  * Keyswitch, Traction, Pump and Work hours count can be shown, identified as K, T, P, W.
  * Hours count retained in display in the event of a controller or logic replacement.
  * Optional Steer Angle indication for vehicles fitted with steer potentiometer.
  * Display connected via single cable, no external power connections necessary.
-

Display example showing diagnostic message


Display example showing forward steer angle indicator



## 11.1.2 STANDARD DISPLAY TECHNICAL SPECIFICATIONS

### 11.1.2.1 **Environmental**

| | |
|---|---|
| Protection (front face): | IP65 |
| Protection (rear): | IP34 |
| Vibration: | 6G, 0-150Hz for 1 hour |
| Operating Temperature: | -5$^{o}$C to +50$^{o}$C |
| Storage Temperature: | -40$^{o}$C to +85$^{o}$C |
| Humidity: | 95% maximum, non-condensing |
| Humidity Resistance: | No functional defects after display is left at 60$^{o}$C and 100% humidity for one hour after freezer use (-30$^{o}$C minimum). |

### 11.1.2.2 **Mechanical**

| | |
|---|---|
| Mounting Hole: | 2” Nominal. (See mechanical drawing) |
| Unit weight: | 0.12 Kg (including mounting bracket) |
| Enclosure: | Injection moulded plastic case, with transparent front facia. |
| Connections: | One 6 way AT socket. |
| Fixings method: | Mounting bracket supplied |

### 11.1.3 **Electrical**

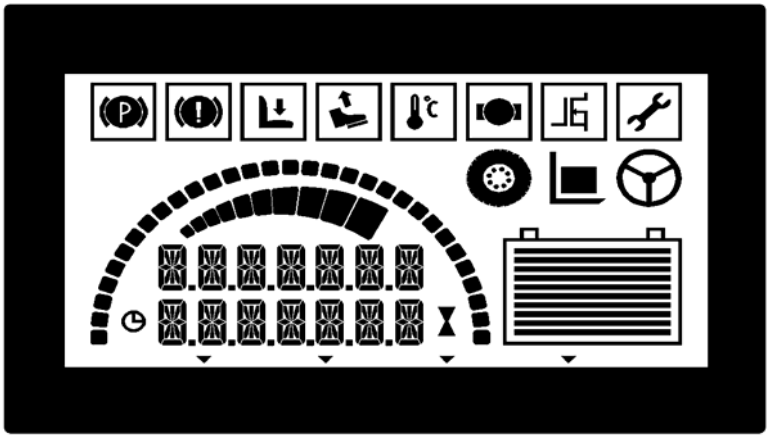
| | |
|---|---|
| Power Supply: | Derived from CANbus |
| Supply Current | 60mA (typical) |

## 11.2 FULL-FEATURE DISPLAY

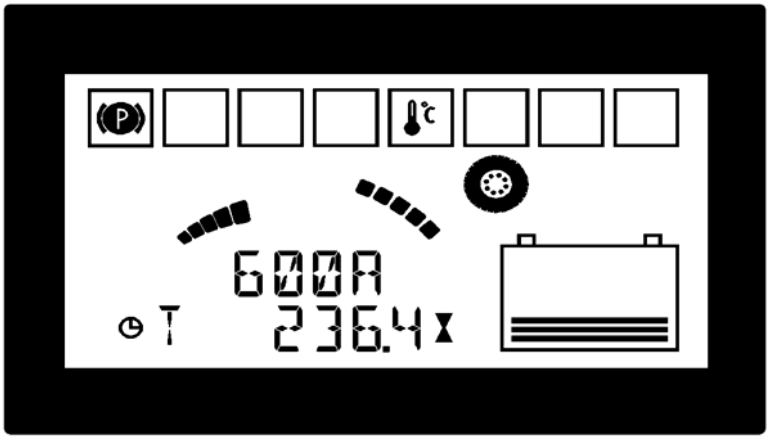
The unit consists of a custom graphic LCD display housed in a SEVCON designed rectangular plastic case. The display incorporates a 10 segment BDI (Battery Discharge Indicator), a 6 digit hours counter and a 14 character area for diagnostic and status messages. The display has 11 warning symbols which can be lit by the controller (via the CANbus) or by 8 active low switch inputs. When there are no diagnostic messages the top line of the message area can be used to indicate one of a number of status readings (see "display related adjustments" below). In addition there are two multipurpose indicators, one designed for steer angle indication and one designed for speed indication, although they can be reprogrammed using the calibrator to show one of a selection of system status readings.

### 11.2.1 FULL-FEATURE DISPLAY FEATURES

* One unit for 24V-96V.
* SEVCON-designed full-custom LCD with LED backlight.
* Readily understandable display format consisting of numbers, text and segments.
* 10 segment BDI indication, with low charge warning and cut-out warnings.
* 14 character text based diagnostic/status display.
* 6 digit hours counter with 0.1 hour indication, and flashing "egg timer" counting symbol.
* Capable of counting up to 99999.9 hours. Equates to 34 years @ 8 hour shift per day
* Keyswitch, Traction, Pump and Work hours count can be shown, identified as K, T, P, W.
* Hours count retained in display in the event of a controller or logic replacement.
* Steer angle indication (indicator #1) for vehicles fitted with steer potentiometer.
* Speed indication (indicator #2), can be reprogrammed via calibrator.
* Text status area can show one of a selection of system status readings.



Full Feature Display with all segments lit.




Full Feature Display showing handbrake, traction motor temperature warning, steer angle (on ind.1), accelerator push (on Ind.2), traction motor current (in status area), traction hours count and BDI.

## 11.2.2 FULL-FEATURE DISPLAY TECHNICAL SPECIFICATIONS

### 11.2.2.1 Environmental

| | |
|---|---|
| Protection: | The enclosure is protected to IP65 |
| Vibration: | 6G, 40-200Hz for 1 hour |
| Operating Temperature: | -20°C to +70°C |
| Storage Temperature: | -40°C to +85°C |
| Humidity: | 100% maximum, with condensing |

### 11.2.2.2 Mechanical

| | |
|---|---|
| Mounting hole: | 128mm x 87mm (see mechanical drawing) |
| Unit weight: | 0.35 Kg. |
| Enclosure: | Injection moulded plastic case, with transparent front facia. |
| Connections: | One 6 way AT socket, One 12-way. |
| Fixings method: | Mounting bracket supplied |

### 11.2.2.3 Electrical

| | |
|---|---|
| Power supply: | Derived from CANbus |
| Supply current: | 60mA (typical) |
| Backlight supply | 14.5V to 150.0V |
| Backlight supply current | 50mA (typical) |

### 11.2.2.4 12-Way Connections

| Pin | Type | Description | |
|---|---|---|---|
| 1 | Digital i/p | Traction | Motor Temperature Warning |
| 2 | Digital i/p | Pump | Motor Temperature Warning |
| 3 | Digital i/p | Power Steer | Motor Temperature Warning |
| 4 | Digital i/p | Traction | Motor Brush Wear |
| 5 | Digital i/p | Pump | Motor Brush Wear |
| 6 | Digital i/p | Power Steer | Motor Brush Wear |
| 7 | Digital i/p | Oil Warning | |
| 8 | Digital i/p | Diagnostic/Service Warning | |
| 9 | 0V | Return for switch inputs, pins 1-8 | |
| 10 | PSU i/p | Battery negative | (backlight supply) |
| 11 | spare | | |
| 12 | PSU i/p | Battery positive | (backlight supply) |

## 11.3 DISPLAY RELATED ADJUSTMENTS

11.3.1 Hours counter, Display status and Contrast adjustments

| Cal. Ref. | DISPLAY Parameter Adjusted | Minimum or default setting. | Maximum or other settings. | Step size. |
|---|---|---|---|---|
| 3.1 | Main Hours | Trac | Pump, Key, Work | n/a |
| 3.2 | Status | Off | Ver # | n/a |
| 3.3 | Contrast (standard only) | 0 | 127 | 1 |
| 3.4 | Indicator 1 (FFD Only) | Off | Ver # | n/a |
| 3.5 | Indicator 2 (FFD Only) | Off | Ver # | n/a |
| 3.6 | Fault Messages | On | Off | n/a |

3.1 The main hours adjustment is used to select which of the hours counters: Keyswitch ("K"), Traction ("T"), Pump ("P") or Work ("W") hours, remains on the display after power-up sequencing, Normally this is Traction ("T").

3.2,4,5 Selects a system status reading for display (or indication on the full-feature display) from: Off, Traction motor current, Traction motor voltage, Pump motor current, Pump motor voltage, vehicle speed in KPH, vehicle speed in MPH, Accelerator push, Steer angle (not available on indicator #2) and display software version number (not available on indicator 1 or 2).

3.3 Sets the contrast of the standard display.

11.3.2 BDI adjustments (Located at the end of the first Traction sub menu 1.4, or in Pump only systems it will reside at the end of the first Pump sub menu 2.4.)

| Cal. Ref. | BDI Parameter Adjusted or displayed | Minimum setting or displayed value | Maximum or other settings | Step size |
|---|---|---|---|---|
| 1.4.1 | xxx % Charge remaining | n/a | n/a | n/a |
| 1.4.2 | Battery Volt xx V | 24V | 96V | 2V |
| 1.4.3 | Reset x.xx V/Cell | 2.00 | 2.50 | V/Cell |
| 1.4.4 | Empty x.xx V/Cell | 1.50 | 1.99 | V/Cell |
| 1.4.5 | Warning xx % | 0% | 90% | 1.0 % |
| 1.4.6 | Cutout xx % | 0% | 90% | 1.0 % |

**WARNING**: The BDI Empty level must be set in accordance with the specification of the battery fitted to the vehicle. Setting the Empty level lower than the battery manufacture's specified discharged level can result in permanent damage to the battery.

1.4.1 Displays the remaining battery charge. No adjustments can be made.

1.4.2 Adjustment used to enter the nominal battery voltage.

1.4.3 Sets the voltage at which the BDI resets to 100% at power up. E.g. the BDI will reset to 100% on a 48V system, with the reset adjustment set to 2.20 Volts per cell, if the battery voltage is above 52.8V = (48V/2)*2.20V.

1.4.4 Sets the voltage at which the BDI indicates the battery is fully discharged, e.g. the BDI will eventually show 0% on a 48V system, with the empty adjustment set to 1.60 Volts per cell, if the battery voltage is below 38.4V = (48V/2)*1.60V.

1.4.5 Sets the discharged level at which the warning threshold is reached, and the unlit segments flash.

1.4.6 Sets the discharged level at which the cut-out threshold is reached. All BDI segments flash, pump operation is cut, and cutback 2 is applied to traction.

## 11.4 BDI OPERATION

The state of battery charge is indicated by 10 segments on the display. When the battery is deemed fully charged, all 10 segments will be lit. When the battery is deemed fully discharged all segments will be extinguished, with each 10% drop in capacity extinguishing 1 segment. There are 5 adjustments associated with the BDI as described on the previous page, adjustable by the hand held calibrator.

When the battery charge drops below an adjustable warning level, typically set to 30%, the remaining lit segments will flash to warn the driver of this. When the charge drops further to below an adjustable cut-out level, typically 20%, all 10 segments will flash. At the cut-out level, Pump operation will be inhibited at the end of its present operating cycle, and cutback 2 personalities will be applied to the Traction.

The state of battery charge is retained even when power is removed, and is stored in the controller's non-volatile EEPROM memory. At power up the display will always indicate the previous state of charge for approximately 1 second, whereupon it will either continue to display this, or revert to a fully charged indication if the battery is deemed to have been charged in the meantime. The BDI system uses an averaged, accurate battery voltage to deduce the state of charge. Pin 10 on connector 2 is the Battery voltage measurement input for the BDI and to maintain accuracy should be connected as close as possible to the actual battery terminals, without overriding safety disconnects.

## 11.5 HOURS COUNTER (INDEPENDENT FROM CONTROLLER HOURS COUNT)

A 6 digit hours counter is provided to indicate Traction pulsing, Pump pulsing and Key switch hours. The last digit displays tenth's of hours, i.e. 6 minute intervals, with the counter capable of displaying up to 99999.9 hours in total. As a guideline, this is equivalent to approximately 34 years operation if the truck was used for an 8 hour shift every day.

At power up the hours count display initially indicates Key switch hours for approximately 3 seconds, followed by Pump pulsing hours for 3 seconds( if applicable), followed by Traction pulsing hours which remains permanently displayed. This order can be changed using the calibrator as described on the previous page. When the hours are being counted, a flashing egg timer symbol is displayed to indicate this. Hours counting accuracy is approx. +/- 2%. The display has its own integral non-volatile memory to retain all the hours counts in the event of the controller or controller logic being replaced.

## 11.6 DIAGNOSTIC/STATUS TEXT MESSAGES

The controller can transmit text messages for diagnostic and status indication. On the standard display these appear over the status area, and on the full-feature display, they also overwrite the hours counter until the fault condition has cleared. This feature can be disabled via personality 3.6 as described on the previous page.

## 11.7 STEER ANGLE INDICATION

On vehicles fitted with a steering potentiometer, typically dual traction motor 3 wheel trucks the angle of the steering wheel can be indicated on the display facia diagram by choosing it from the list of system status readings. On the standard display, the steer angle is shown in the status area, and on the full-feature display indicator 1 is used.

# 12 POWER CIRCUIT DESCRIPTIONS

The main switching element of the SC2000 consists of a bank of power Mosfet transistors connected in parallel. These are switched at high frequency (15.7khz) to give silent operation. Switching speeds have been optimised to minimise switching losses.

Fast-recovery Freewheel diodes, also connected in parallel but arranged to share current, are used to maintain circulating current around the motor when the main Mosfets are turned off.

Both the Mosfets and Freewheel diodes have their temperatures monitored. The software will cutback motor current to prevent either thermal stress, or operation outside their safe operating areas.

Electrolytic capacitors are fitted internally between B+ve and B-ve to maintain constant current in the battery leads and to keep a constant battery voltage across the controller.

In Traction power frames a Plug Diode is internally connected across the motor armature to limit the generated voltage during plugging so that controlled braking can be achieved. This diode is not necessary for Pump motor controllers.

On traction controllers, Regen is achieved by adding an extra single pole change over contactor and an optional regen diode which connects the top of the motor armature to B-ve during braking, to allow circulating generated current to flow round the motor loop after the direction contactors have been reversed and the motor excited. The generated armature voltage charges the motor field with current when the MOSFETs are on. When they are off, this current flows through the freewheel diodes back into the battery. This has the effect of returning a small amount of energy back to the battery and minimising heat dissipation in the motor during braking.

A current shunt is connected in series with the motor armature to monitor motor currents, during all operations including drive, regen and plug braking modes.

On traction controllers the direction contactors should be used to switch the armature. A line contactor can be used to offer reverse battery connection protection, minimise any battery connector arcing when powering up, and to give a mechanical break in pump controller systems. The line contactor is optional.

On Traction dual motor non proportional controllers, an extra set of direction contactors are required to switch the second motor's armature to be able to offer direction control, inner motor drop out, and inner motor reversal during cornering. A balancing contactor connected between the two armatures is usually necessary to prevent circulating currents in braking. Traction dual motor proportional controllers also require an extra set of direction contactors for direction control, although two independent choppers are utilised to provide true proportional control during cornering. No balancing contactor is required for proportional systems.

Bypass operation is possible on both traction and pump systems to short out the main Mosfet devices for maximum efficiency and high speed or high current operation. Field Weakening operation is also possible on both traction and pump controllers by controlling a contactor to switch in resistor in parallel with the motor field. An output for controlling a power steer contactor is also provided.

# 13 INSTALLATION

13.1 The controller should be bolted down to a flat (0.2mm max. deviation) **paint free** surface that has been lightly coated with a thermal transfer compound, such as G6451 or Dow Corning heatsink compound, by the 6 fixing holes provided. Care should be taken not to trap any wires, etc., under the controller. The mounting surface MUST be a substantial metal section of the truck for the full controller ratings to be achieved.

13.2 Power connections should be made with flexible heat resisting cables of suitable cross-sectional area for the current to be carried. These should be terminated in soldered or crimped lugs attached to controller and the contactors. Note that nuts and washers are supplied for the M8 connections on the controller. A battery-disconnect switch should be used (EC Directive).

13.3 The contactors specified for use with the controller are Albright SW180 series (Pump and Traction Bypass and Regen), Albright SW80 (Power Steer and Field Weakening), Albright SW200 (Line) and Albright DC182 (Forward/Reverse). Contactors are to be rated for intermittent use with the exception of the Line and Power Steer contactors which must be rated for continuous use. When alternative manufacturers contactors are used, coil currents, pull-in and drop-out times should be investigated to ensure compatible operation.

13.4 The contactor mounting plane can affect performance, contactors should never be mounted with their terminal studs vertically down. For further applications information on contactors, please consult SEVCON.

13.5 The controller may be supplied as a stand-alone unit or pre-wired onto a baseplate with contactors etc. If the controller is 'stand-alone', both Connectors 1 and 2 will be used. If a 'panel' is supplied, only Connector 1 will be used as Connector 2 will contain the contactor wiring. The mating halves of the connectors can be supplied with the controller as a 'loose equipment kit'.

13.6 Control wiring connections should be made using 1.00mm$^2$ (AWG#18) or equivalent stranded wire. The correct pressure release crimping tools MUST be used for long term connection reliability.

13.7 The main battery cable should be fused with a suitable air-break fuse. The keyswitch line must also be fused at a level not exceeding 10 A when using the specified Albright contactors. The BDI measure input, connector B pin 10 should have a series 1 amp fuse fitted

13.8 The return wiring for the accelerators should be connected to the B- terminal on the controller to prevent large currents altering accelerator signals.

13.9 Fixing torque for power connectors

| | |
|---|---|
| **M10 terminals** | **14NM ±0.6NM** |
| **M8 terminals** | **11NM +0.5NM, -0.2NM** |

# 14 EMC GUIDELINES.

The following guidelines are intended to help vehicle manufacturers to meet the requirements of the EC directive 89/336/EEC for Electromagnetic Compatibility.

Any high speed switch is capable of generating harmonics at frequencies that are many multiples of its basic operating frequency. It is the objective of a good installation to contain or absorb the resultant emissions.

All wiring is capable of acting as a receiving or transmitting antenna. Wiring should be arranged to take maximum advantage of the structural metal work inherent in most vehicles. Vehicle metalwork should be electrically linked with conductive braids.

## 14.1 POWER CABLES

All cables should be routed within the vehicle framework and kept as low in the structure as is practical - a cable run within a main chassis member is better screened from the environment than one routed through or adjacent to an overhead guard.

Power cables should be kept short to minimise emitting and receiving surfaces

Shielding by the structure may not always be sufficient - cables run through metal shrouds may be required to contain emissions.

Parallel runs of cables in common circuits can serve to cancel emissions - the battery positive and negative cables following similar paths is an example.

Tie all cables into a fixed layout and do not deviate from the approved layout in production vehicles. A re-routed battery cable could negate any approvals obtained.

## 14.2 SIGNAL CABLES

All wiring harnesses should be kept short.

Wiring should be routed close to vehicle metalwork.

All signal wires should be kept clear of power cables or made from screened cable

Control wiring should be kept clear of power cables when it carries analogue information - for example, accelerator wiring.

Tie all wiring securely and ensure wiring always follows the same layout.

## 14.3 CONTROLLER

Thermal and EMC (emissive) requirements tend to be in opposition.

Additional insulation between the controller assembly and the vehicle frame work reduce capacitive coupling and hence emissions but tend to reduce thermal ratings. A working balance needs to be established by experiment.

The complete installation should be documented, in detail, and faithfully reproduced on all production vehicles. When making changes, consider their effect on compliance ahead of any consideration of cost reduction or other “improvement”.

**STANDARD SEVCON POWER UP, SEAT SWITCH AND SRO SEQUENCING DESCRIPTION**

**KEY SWITCH POWER UP TRUTH TABLE (NO SRO ENABLED)**

| | Key Sw. | Seat Sw. | Direction Sw. | FS1 Sw. | Drive | Fault Indicated |
|---|---|---|---|---|---|---|
| 1-8 | 0 | x | x | x | No | None |
| 9 | 1 | 0 | 0 | 0 | No | None |
| 10 | 1 | 0 | 0 | 1 | No | None |
| 11 | 1 | 0 | 1 | 0 | No | None |
| 12 | 1 | 0 | 1 | 1 | No | **Seat Fault** |
| 13 | 1 | 1 | 0 | 0 | No | None |
| 14 | 1 | 1 | 0 | 1 | No | None |
| 15 | 1 | 1 | 1 | 0 | No | None |
| 16 | 1 | 1 | 1 | 1 | **Yes** | None |

**KEY SWITCH POWER UP SEQUENCE TABLE (NO SRO ENABLED)**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Key | Seat | Direction | FS1 | **Yes** | None |
| 2 | Key | Seat | FS1 | Direction | **Yes** | None |
| 3 | Key | Direction | Seat | FS1 | No | **Seat Fault** |
| 4 | Key | Direction | FS1 | Seat | No | **Seat Fault** |
| 5 | Key | FS1 | Seat | Direction | No | **Seat Fault** |
| 6 | Key | FS1 | Direction | Seat | No | **Seat Fault** |
| 7 | Seat | Key | Direction | FS1 | **Yes** | None |
| 8 | Seat | Key | FS1 | Direction | **Yes** | None |
| 9 | Seat | Direction | Key | FS1 | No | **Power Up Fault** |
| 10 | Seat | Direction | FS1 | Key | No | **Power Up Fault** |
| 11 | Seat | FS1 | Key | Direction | No | **Power Up Fault** |
| 12 | Seat | FS1 | Direction | Key | No | **Power Up Fault** |
| 13 | Direction | Key | Seat | FS1 | No | **Power Up Fault** |
| 14 | Direction | Key | FS1 | Seat | No | **Power Up Fault** |
| 15 | Direction | Seat | Key | FS1 | No | **Power Up Fault** |
| 16 | Direction | Seat | FS1 | Key | No | **Power Up Fault** |
| 17 | Direction | FS1 | Key | Seat | No | **Power Up Fault** |
| 18 | Direction | FS1 | Seat | Key | No | **Power Up Fault** |
| 19 | FS1 | Key | Seat | Direction | No | **Power Up Fault** |
| 20 | FS1 | Key | Direction | Seat | No | **Power Up Fault** |
| 21 | FS1 | Seat | Key | Direction | No | **Power Up Fault** |
| 22 | FS1 | Seat | Direction | Key | No | **Power Up Fault** |
| 23 | FS1 | Direction | Key | Seat | No | **Power Up Fault** |
| 24 | FS1 | Direction | Seat | Key | No | **Power Up Fault** |

**SEAT SWITCH TRUTH TABLE (NO SRO ENABLED)**

| | Seat Sw. | Seat Timer | Direction Sw. | FS1 Sw. | Drive | Fault Indicated |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | No | No |
| 2 | 0 | 0 | 0 | 1 | No | No |
| 3 | 0 | 0 | 1 | 0 | No | **Seat Fault** |
| 4 | 0 | 0 | 1 | 1 | No | **Seat Fault** |
| 5 | 0 | 1 | 0 | 0 | No | No |
| 6 | 0 | 1 | 0 | 1 | No | No |
| 7 | 0 | 1 | 1 | 0 | No | No |
| 8 | 0 | 1 | 1 | 1 | **Yes** | No |
| 9 | 1 | x | 0 | 0 | No | No |
| 10 | 1 | x | 0 | 1 | No | No |
| 11 | 1 | x | 1 | 0 | No | No |
| 12 | 1 | x | 1 | 1 | **Yes** | No |
| 13 | 1 | x | 0 | 0 | No | No |
| 14 | 1 | x | 0 | 1 | No | No |
| 15 | 1 | x | 1 | 0 | No | No |
| 16 | 1 | x | 1 | 1 | **Yes** | No |

**SEAT SWITCH SEQUENCE TABLE (NO SRO ENABLED)**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Seat | Direction | FS1 | **Yes** | No |
| 2 | Seat | FS1 | Direction | **Yes** | No |
| 3 | Direction | Seat | FS1 | No | **Seat Fault** |
| 4 | Direction | FS1 | Seat | No | **Seat Fault** |
| 5 | FS1 | Seat | Direction | No | **Seat Fault** |
| 6 | FS1 | Direction | Seat | No | **Seat Fault** |

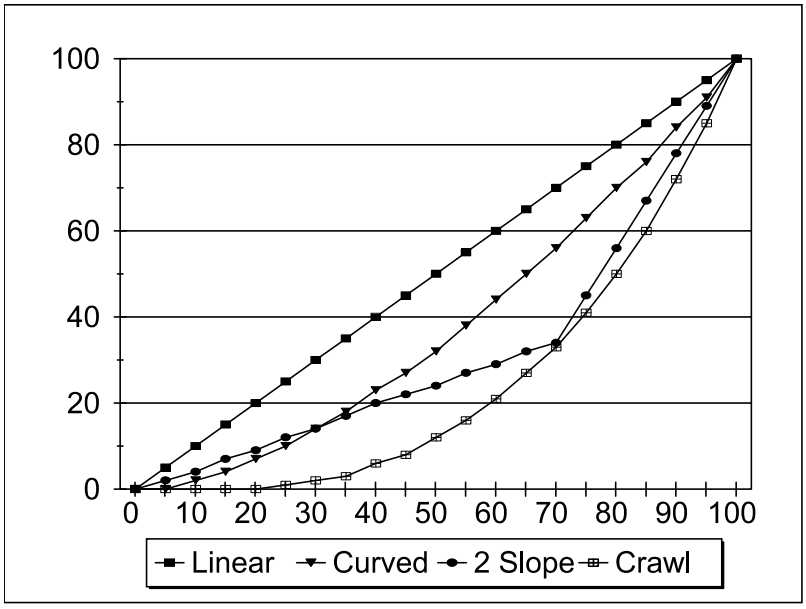
SRO (Static Return to Off) TRUTH TABLE

| | Direction Sw. | FS1 Sw. | Drive | Fault Indicated |
|---|---|---|---|---|
| 1 | 0 | 0 | No | None |
| 2 | 0 | 1 | No | None |
| 3 | 1 | 0 | No | None |
| 4 | 1 | 1 | **Yes** | None |

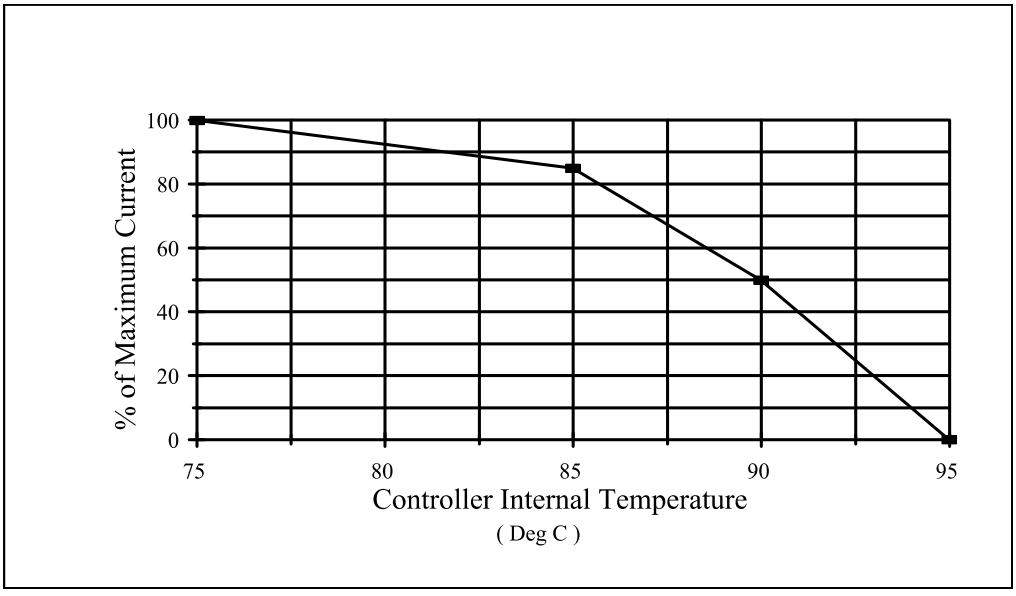
**SRO (Static Return to Off) SEQUENCE TABLE**

| | | | | |
|---|---|---|---|---|
| 1 | Direction | FS1 | **Yes** | None |
| 2 | FS1 | Direction within 2 seconds | **Yes** | None |
| 3 | FS1 | Direction after 2 seconds | No | **SRO FAULT** |

## Accelerator Characteristics

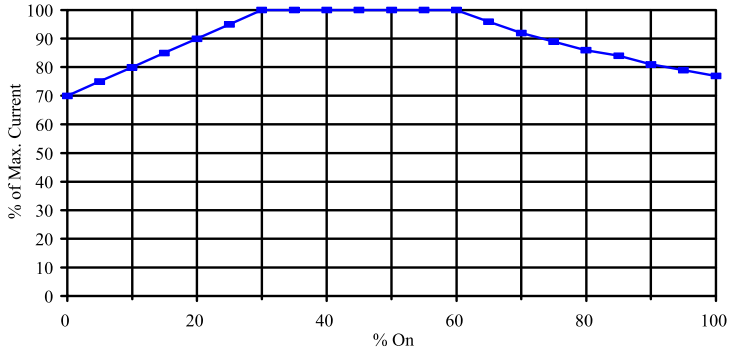



## Thermal Cutback Characteristic

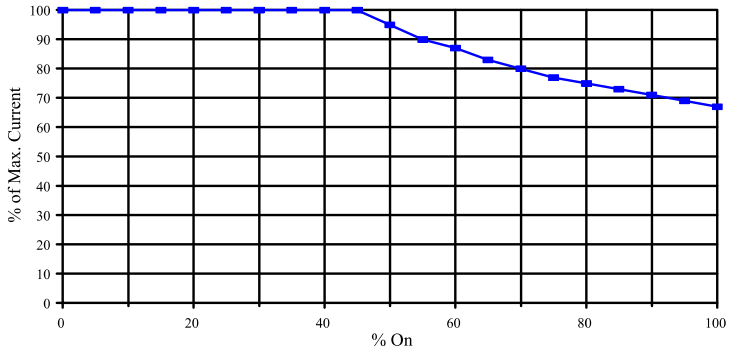



## Safe Operating Area Graphs

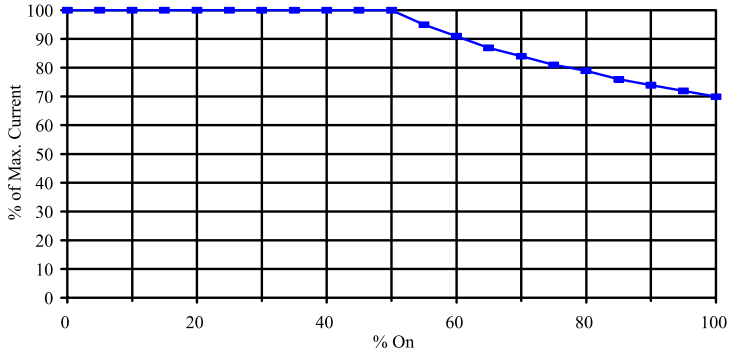
**24-48V 500/650A Controllers**



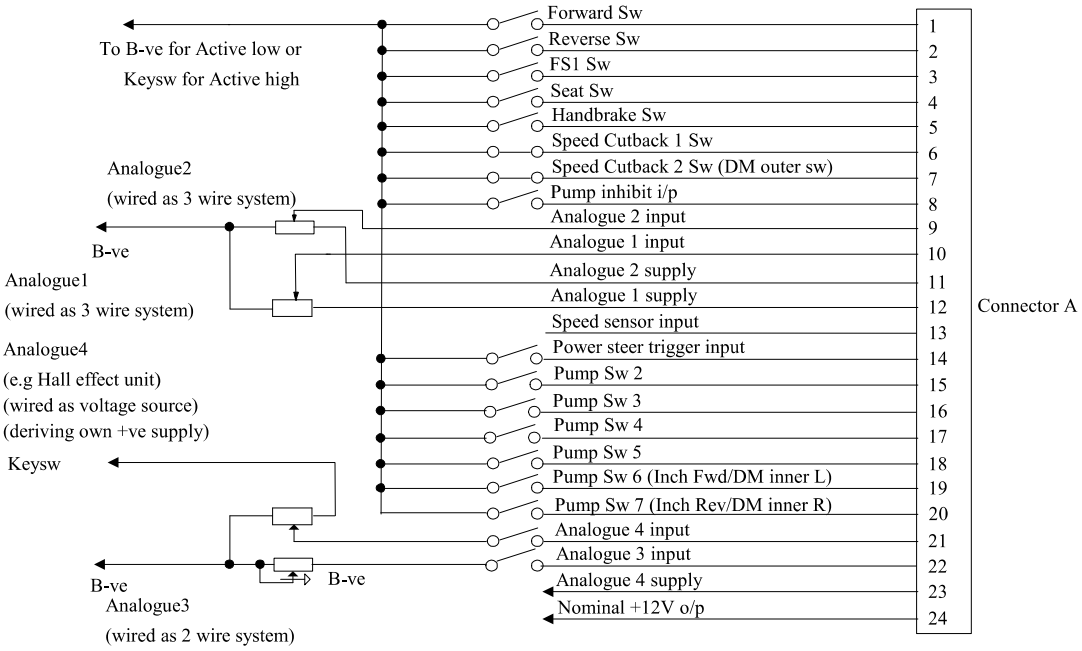

**72-96V 650A Controllers**

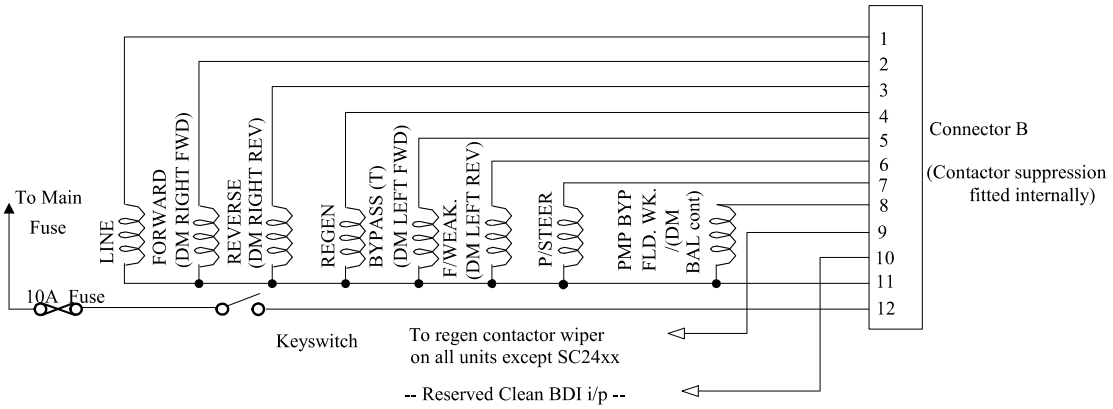


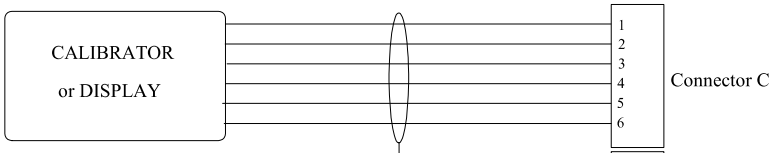

**72-80V 500A Controllers**



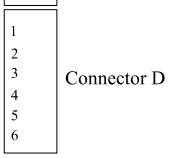
# Fig. 1 - Control Wiring Diagram



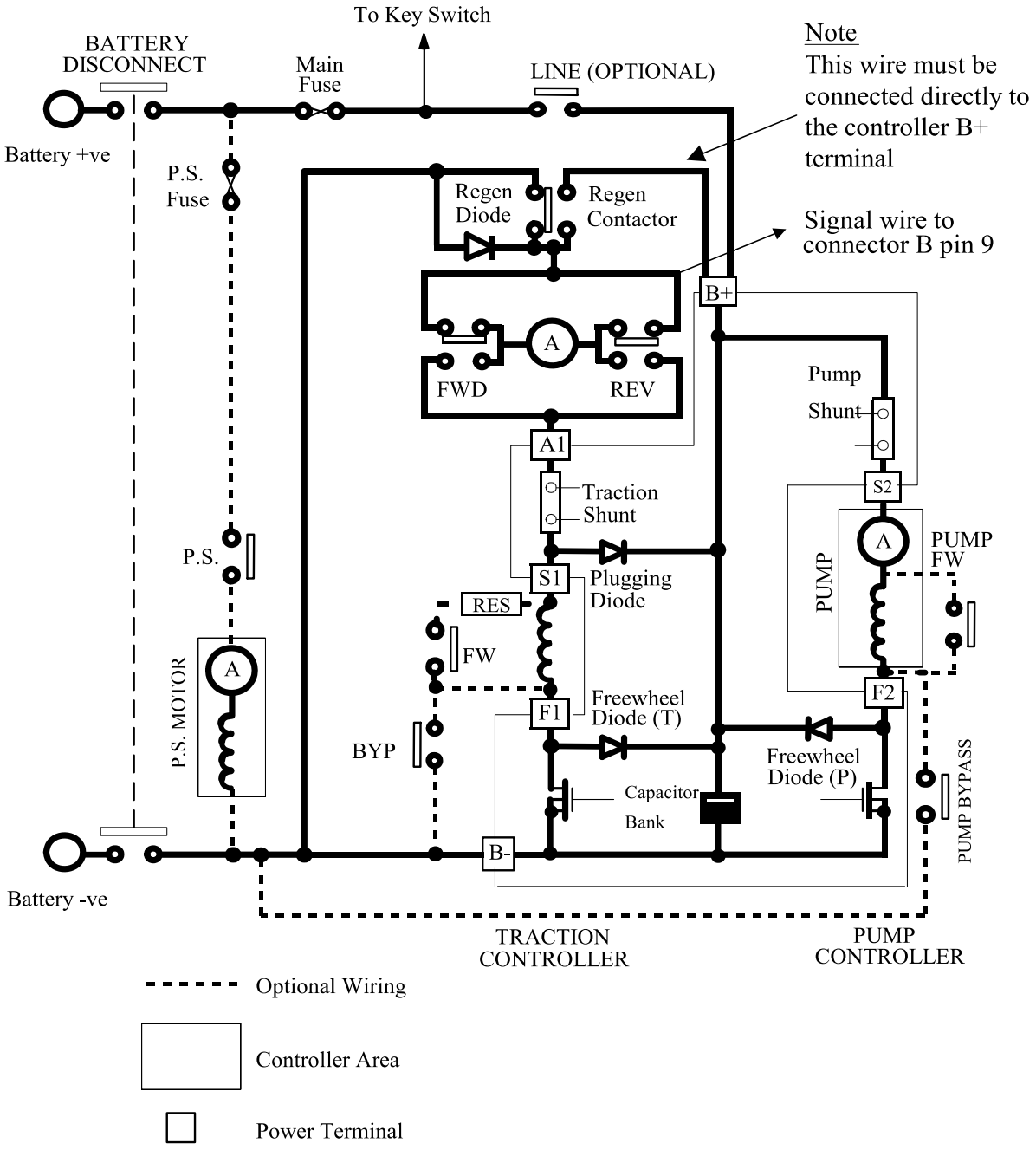




Cable supplied with Calibrator/ Display




| Unit | Analogue1 | Analogue2 | Analogue3 | Analogue4 |
|---|---|---|---|---|
| SC22XX | Traction | Footbrake | Economy | Pump |
| SC22XX | Traction | Footbrake | Economy | Not Used |
| SC23XX | Not Used | Not Used | Not Used | Pump |
| SC24XX | Traction | Steer Pot | Footbrake | Pump |
| SC25XX | Traction | Steer Pot | Footbrake | Economy |

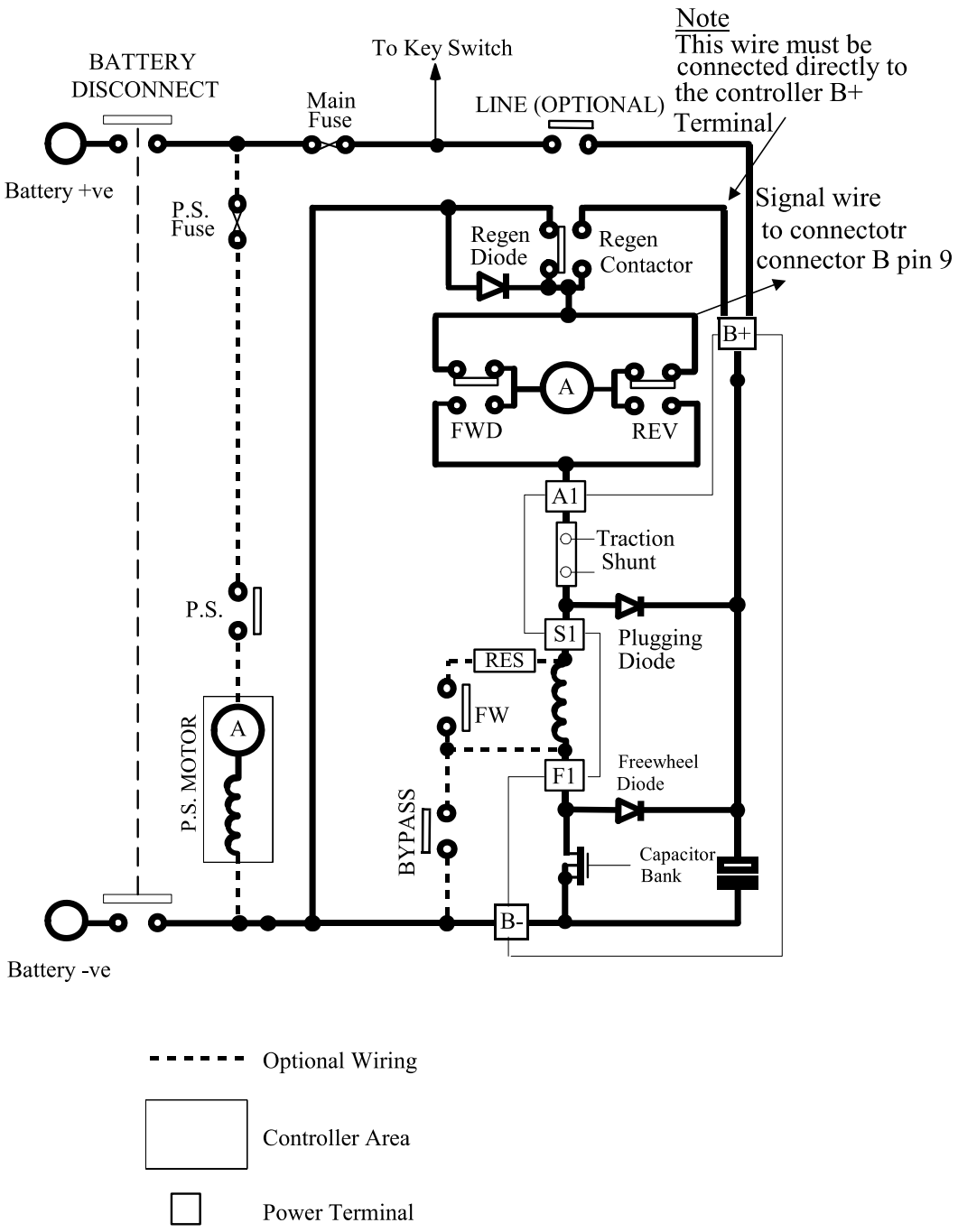
## Fig. 2 - SC21xx Power Circuit Traction Regen +Pump




**Note 1 : Do Not supply any auxilliary equipment from the controller B+ Terminal.**

**2 : For Plug only Traction controllers, there is no Regen contactor or diode.**

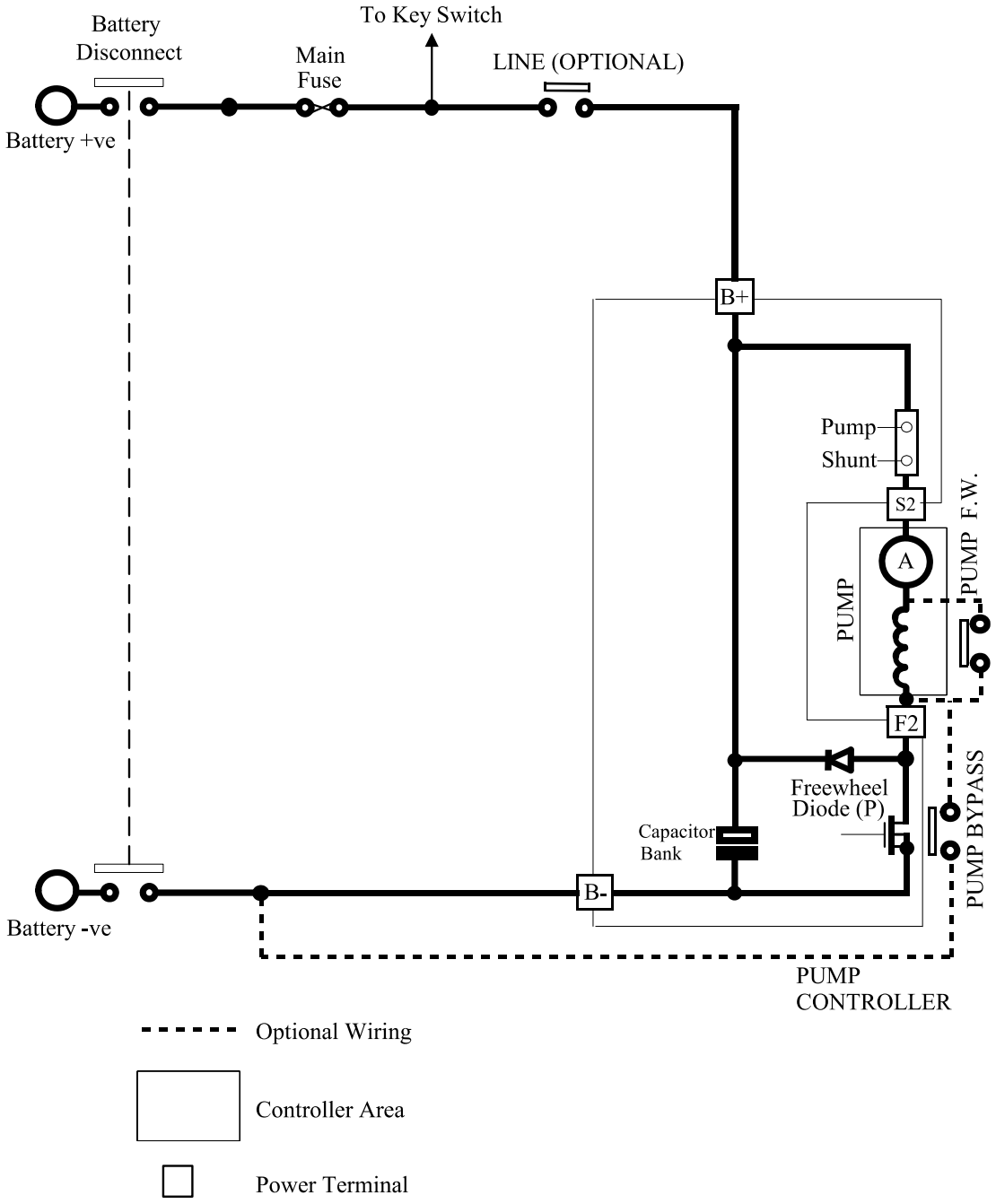
## Fig. 3 - SC22xx Power Circuit Traction Regen




**Note 1 : Do Not Supply any Auxiliary equipment from the controller B+ terminal.**

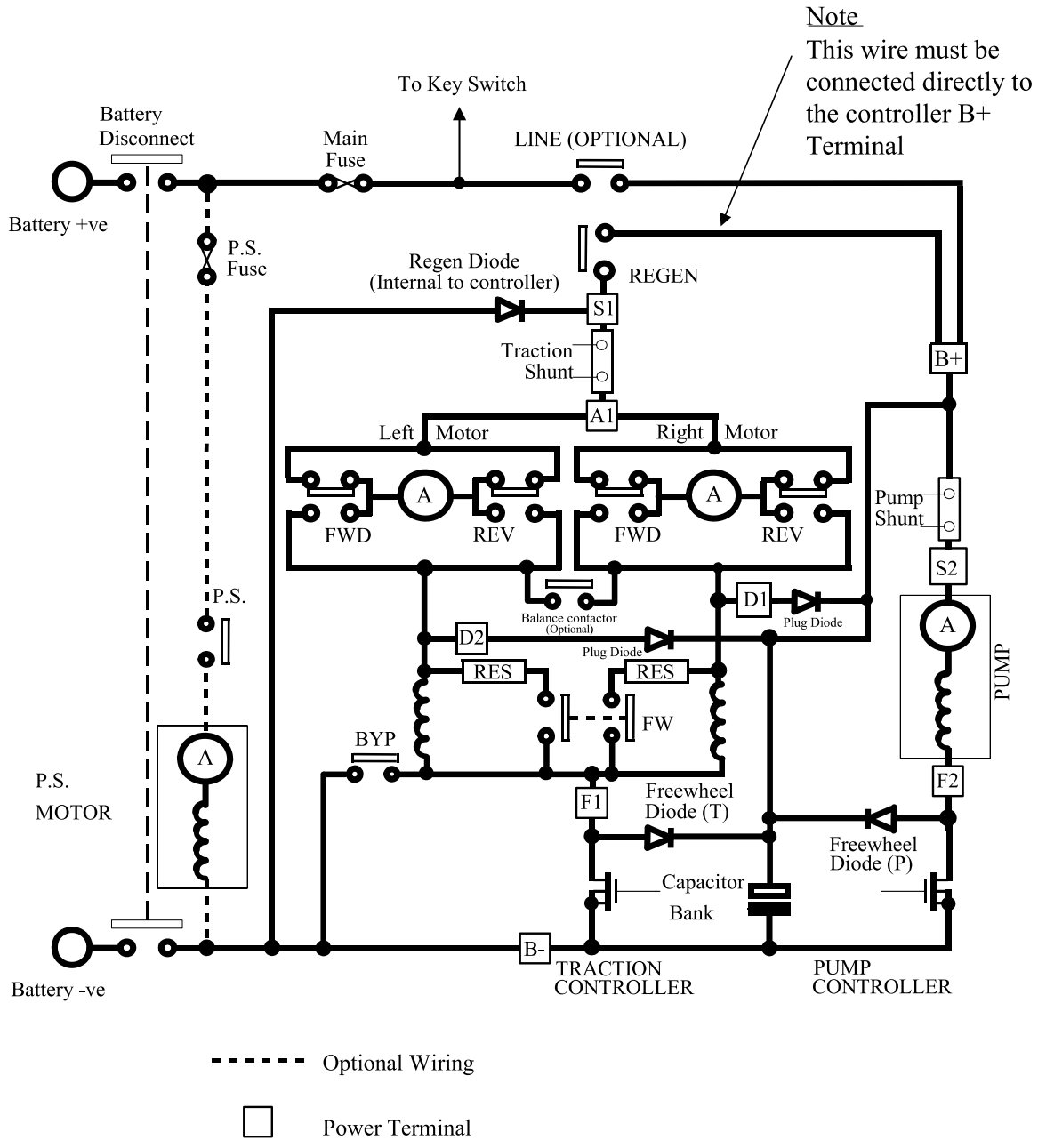
**2 : For Plug only Traction controllers, there is no Regen contactor or diode.**

## Fig. 4 - SC23xx Power Pump




Note 1 : Do not supply any auxiliary equipment from the controller B+ terminal.

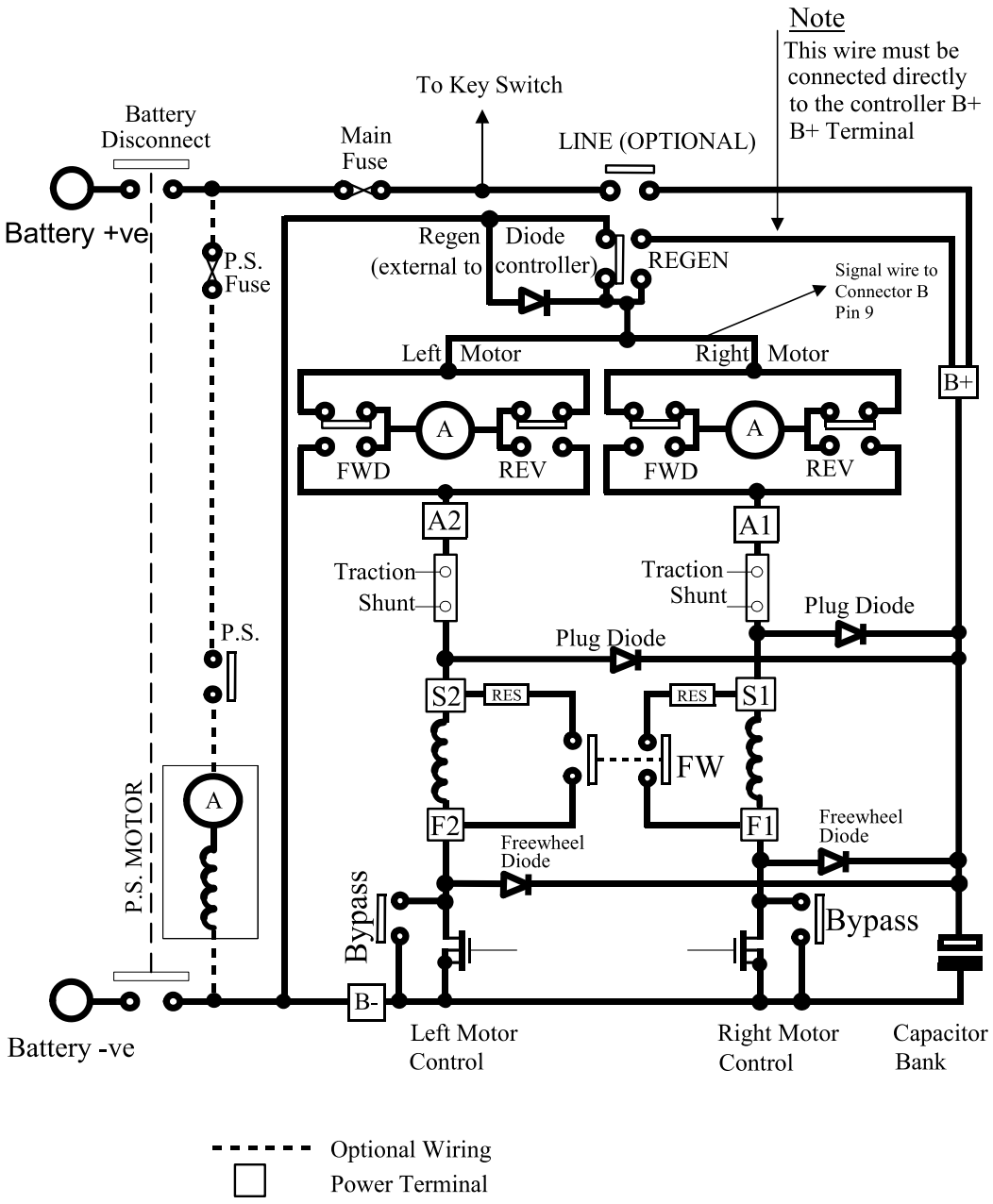
## Fig. 5 - SC24xx Power Circuit Dual Motor Traction Regen, Non-Proportional + Pump.




Note 1 : Do Not supply any auxilliary equipment from the controller B+ Terminal.

2 : For Plug only Traction controllers, there is no Regen contactor or diode.

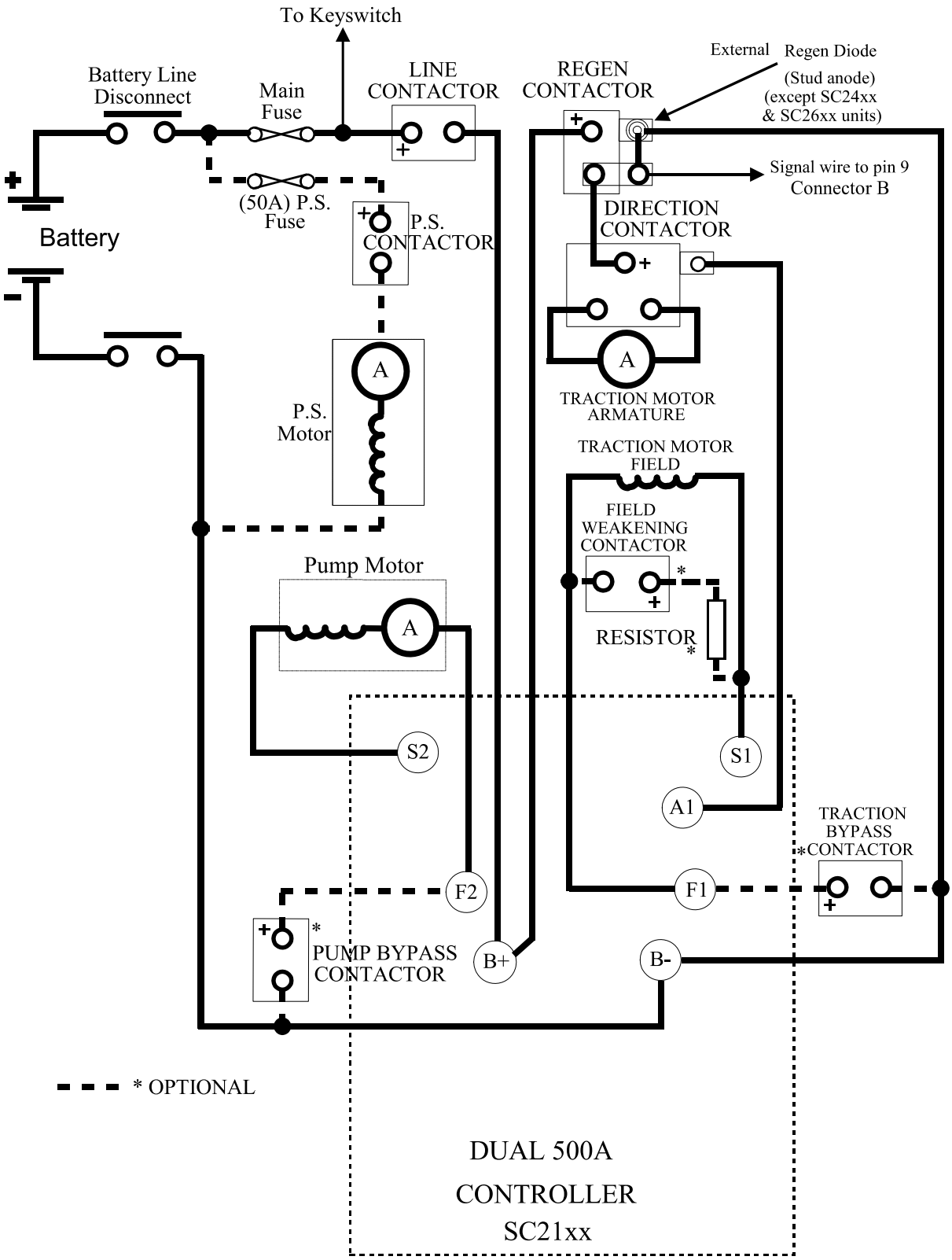
## Fig. 6 - SC25xx Power Circuit Dual Motor Traction + Traction Regen, Proportional.



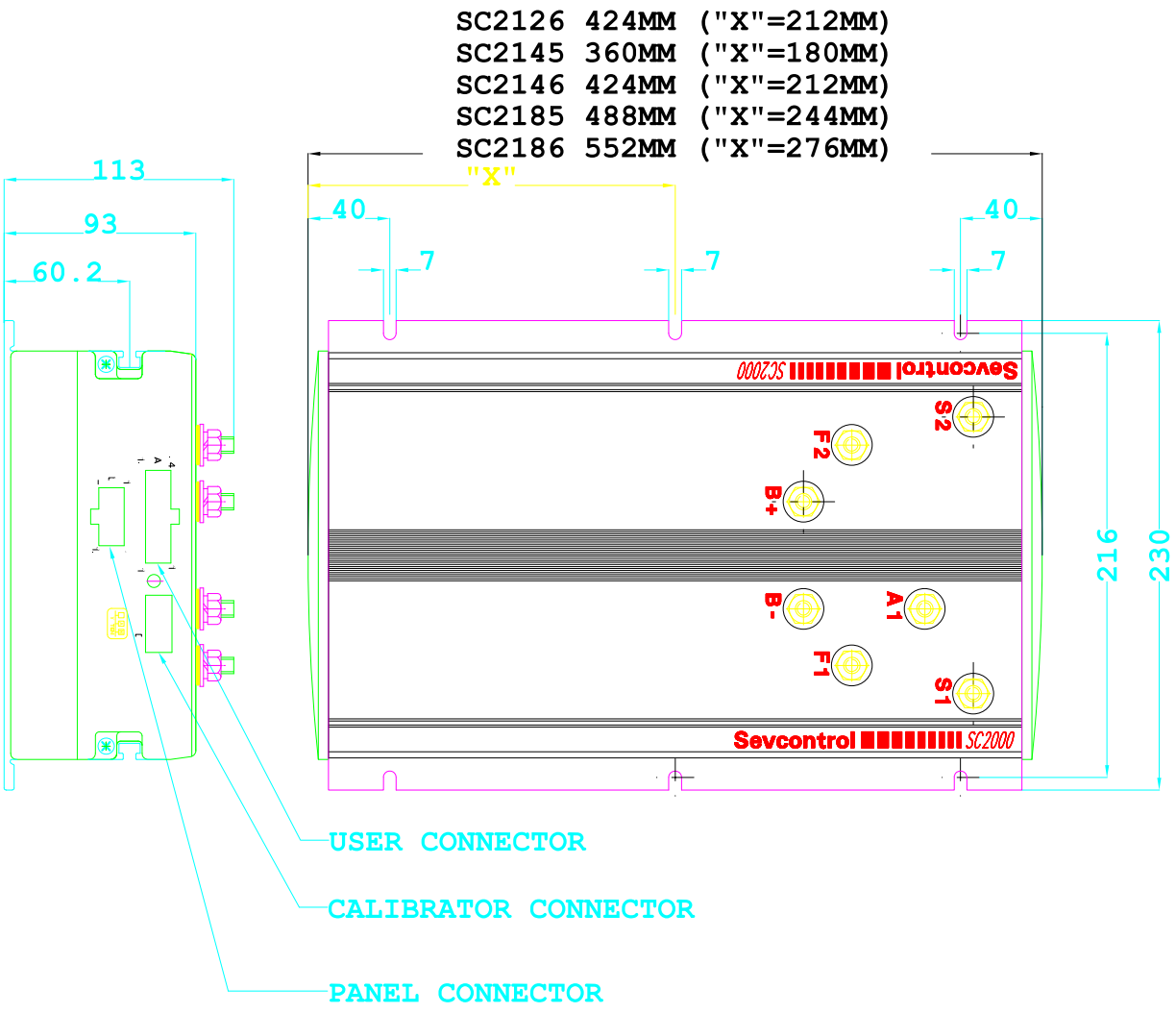

Note 1 : Do Not supply any auxilliary equipment from the controller B+ Terminal.

2 : For Plug only Traction controllers, there is no Regen contactor or diode.

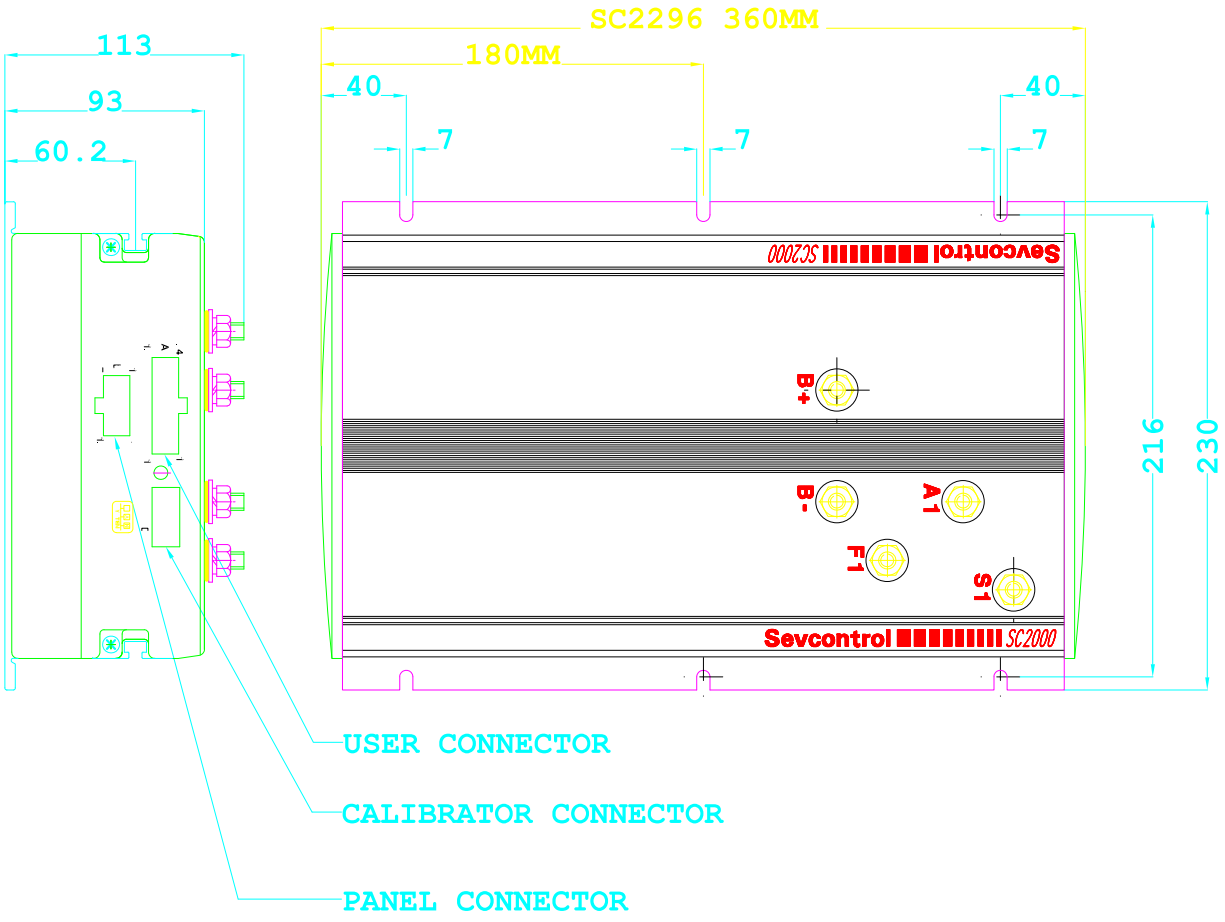
## Fig. 7 - Sample Power Wiring Layout Diagram



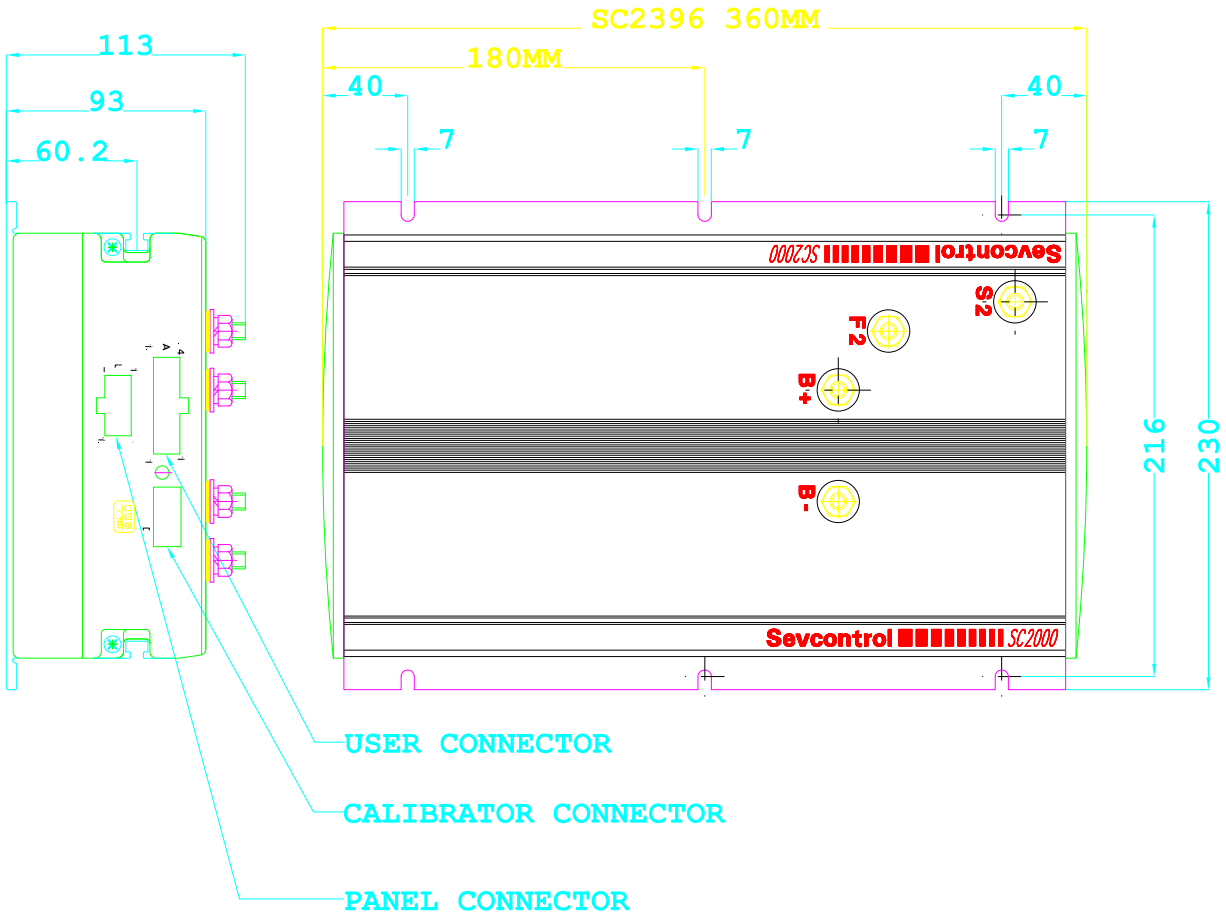
## Mechanical Dimensions - Traction and Pump



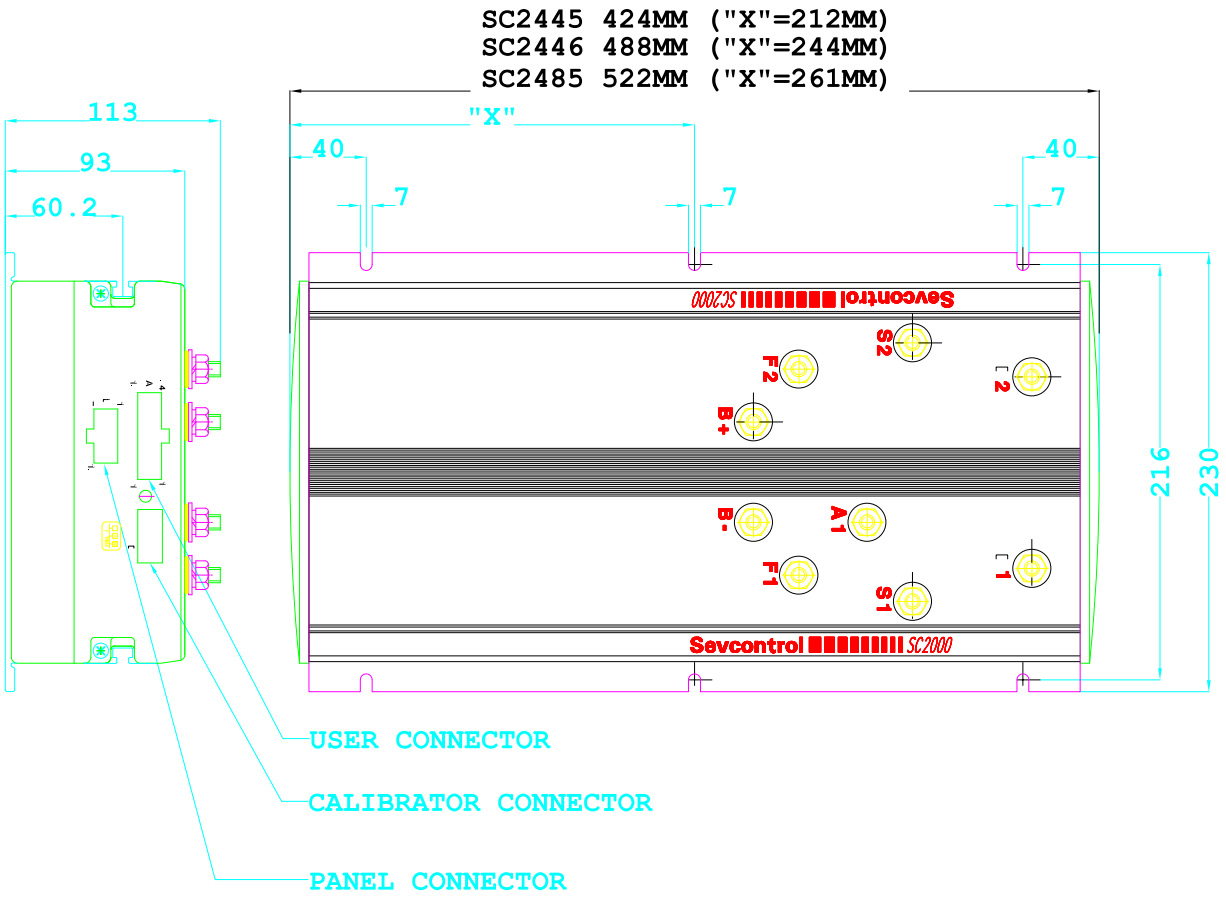
## Mechanical Dimensions - Stand-alone Traction



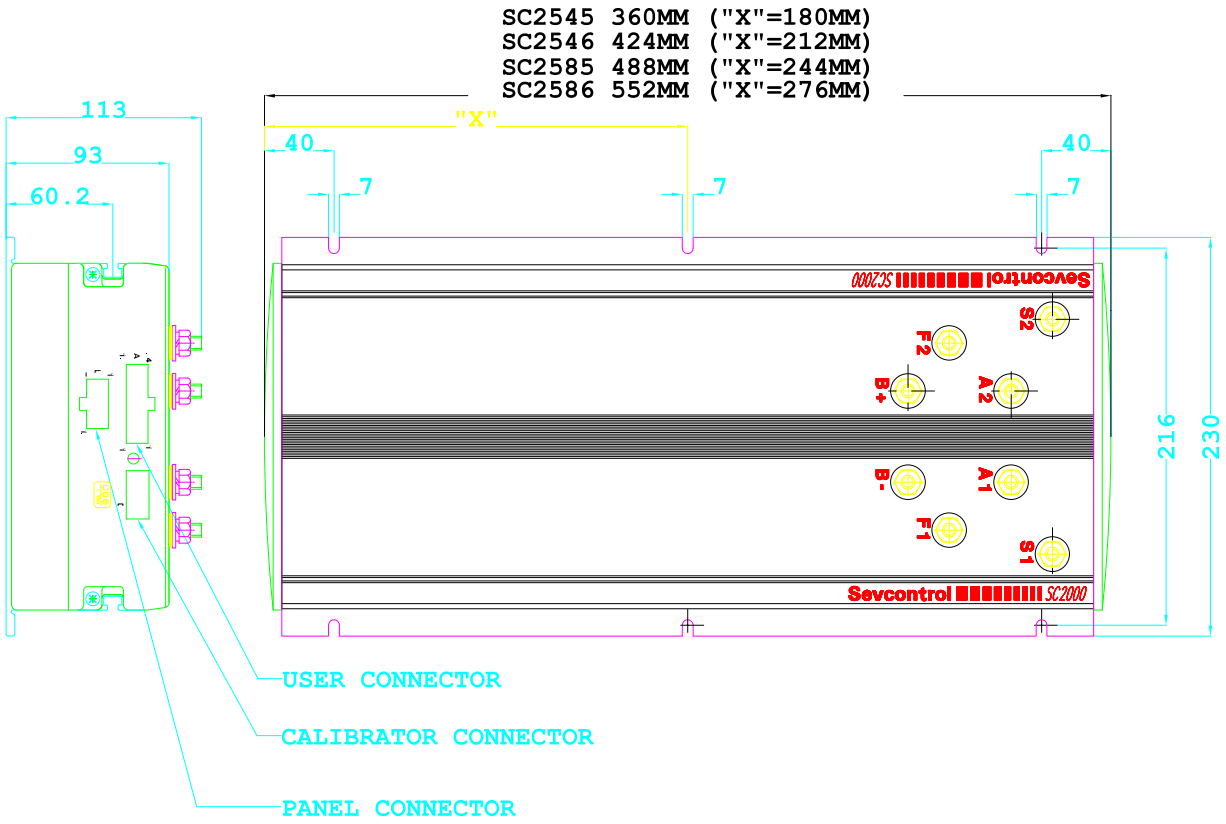
## Mechanical Dimensions - Stand-alone Pump



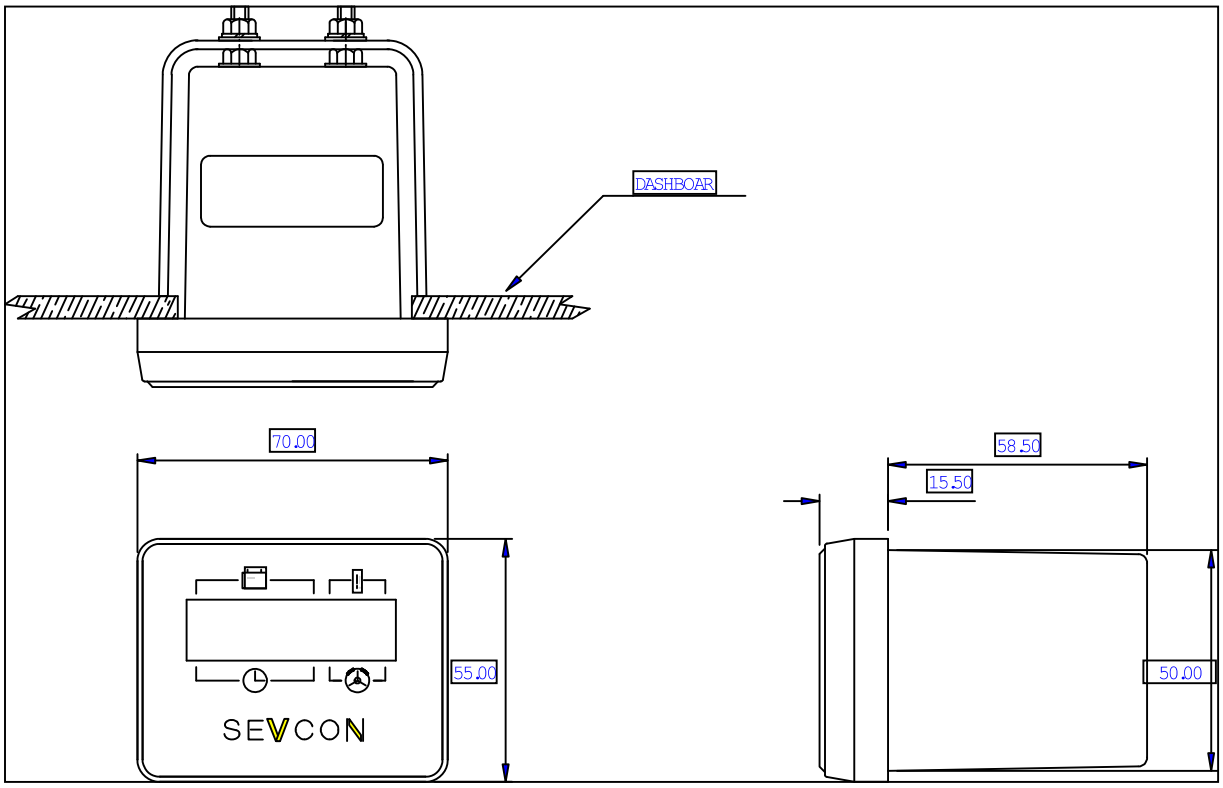
## Mechanical Dimensions - Traction Dual Motor Non-proportional and Pump



## Mechanical Dimensions - Traction Dual Motor Proportional and Pump (via contactor)



## Mechanical Dimensions - Standard Dashboard Display



## Mechanical Dimensions - Full Feature Display