

Sevcon MillipaK Regen SEM Controller

User Manual - FLT System Version: F_UK0035

Document History

Document History

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Introduction

The MillipaK Regen SEM (Separately Excited Motor) range of controllers provides a new range of power frames for 24V-48V, 180A - 500A, in one of two small, highly efficient packages. This is achieved using a Sevcon patented power switching scheme and radical new construction techniques, which enable large powers to be incorporated into very small packages.

The MillipaK provides a completely sealed (IP66) unit containing power and logic circuitry.

MillipaK supports Sevcon's existing MOS90 calibrator and the PCpaK application for adjustment of vehicle performance characteristics. MillipaK is ideally suited to applications requiring a single traction controller, for example walkies, golf cars and basic ride-on trucks.

The MillipaK is FLASH microprocessor based, enabling field re-programming for new features, and offers numerous user set-up options. The MillipaK uses high frequency (silent) MOSFET power switching technology, to control a SEM power frame comprising Armature circuit and Field Bridge. Armature and Field currents are monitored. Motor feedback should not be necessary. Controllers have been designed to satisfy the requirements of the relevant UL and EC standards.

The MillipaK supports a Complementary Switching mode to provide reduction braking on inclines. This is particularly useful for Golf Car applications.

Safety

The MillipaK controller contains a triple fail-safe system to provide 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.

The controller must be used with a line contactor as indicated in the wiring diagrams. 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 molding.

The MillipaK controller may be used with suitable onboard chargers, as supplied by Sevcon.

There are several software features which are intended to prevent inadvertent or unexpected vehicle movement:

- SRO
- Accelerator power up fault
- Sequence checking.

Some of these features cannot be disabled and the appropriate signals must be supplied to the controller before drive is allowed.

Installation

The small footprint of the MillipaK controller provides the user with maximum flexibility with regard to mounting options. The following section provides details of criteria that should be considered when situating the controller on a vehicle.

Mounting

The MillipaK and MillipaK HP units provide 4 x M6 clearance holes for mounting. The controllers should be mounted onto a metal base plate, as large as possible to provide heat-sinking. The surface finish should be flat, clean and burr free and thermal compound should be applied to the controller base before fitting.

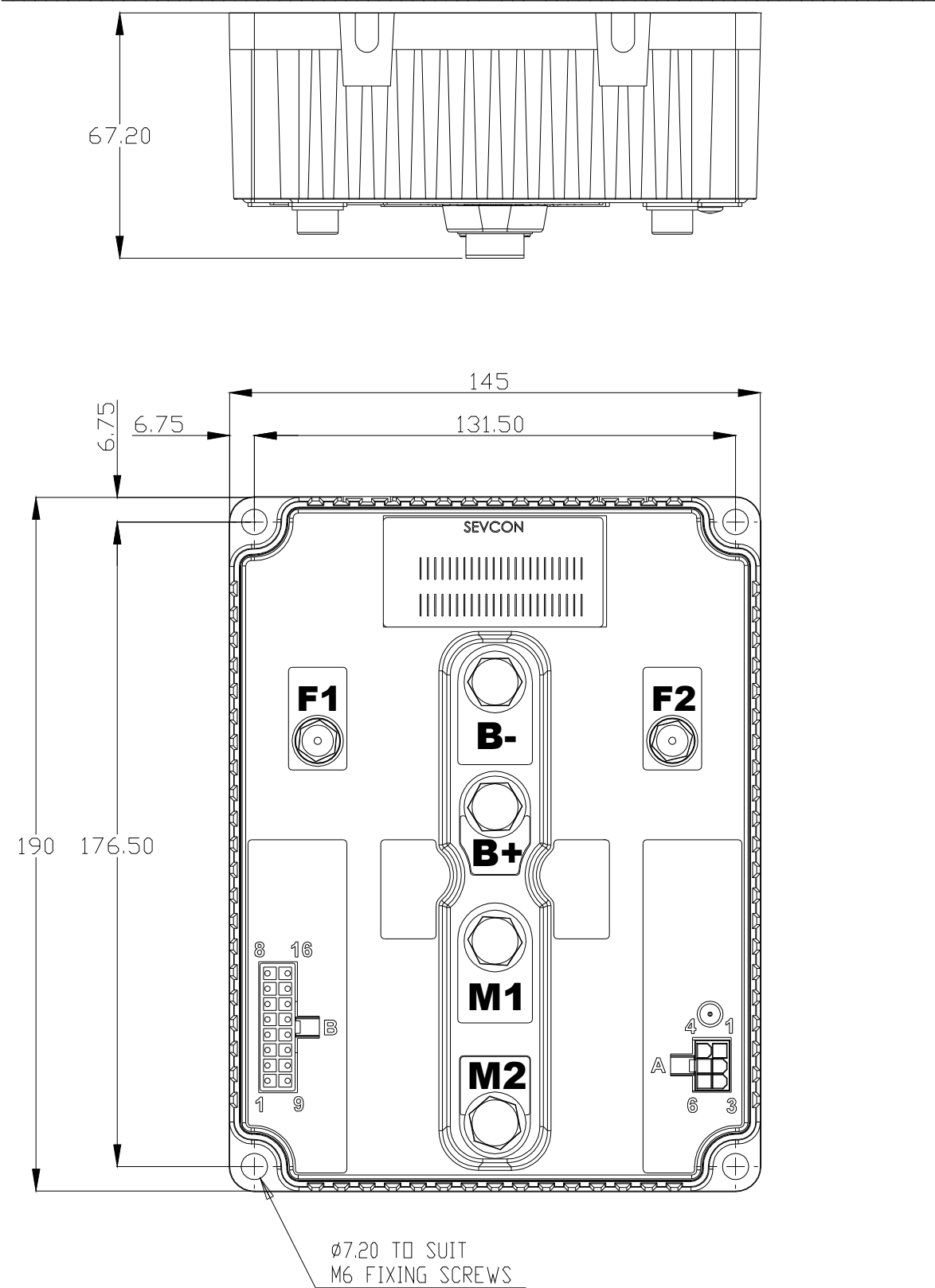


Figure 1: MillipaK HP Dimensions

Maximum terminal torque: M8 terminals – 10NM
M6 terminals – 7NM

MillipaK SEM Power Wiring

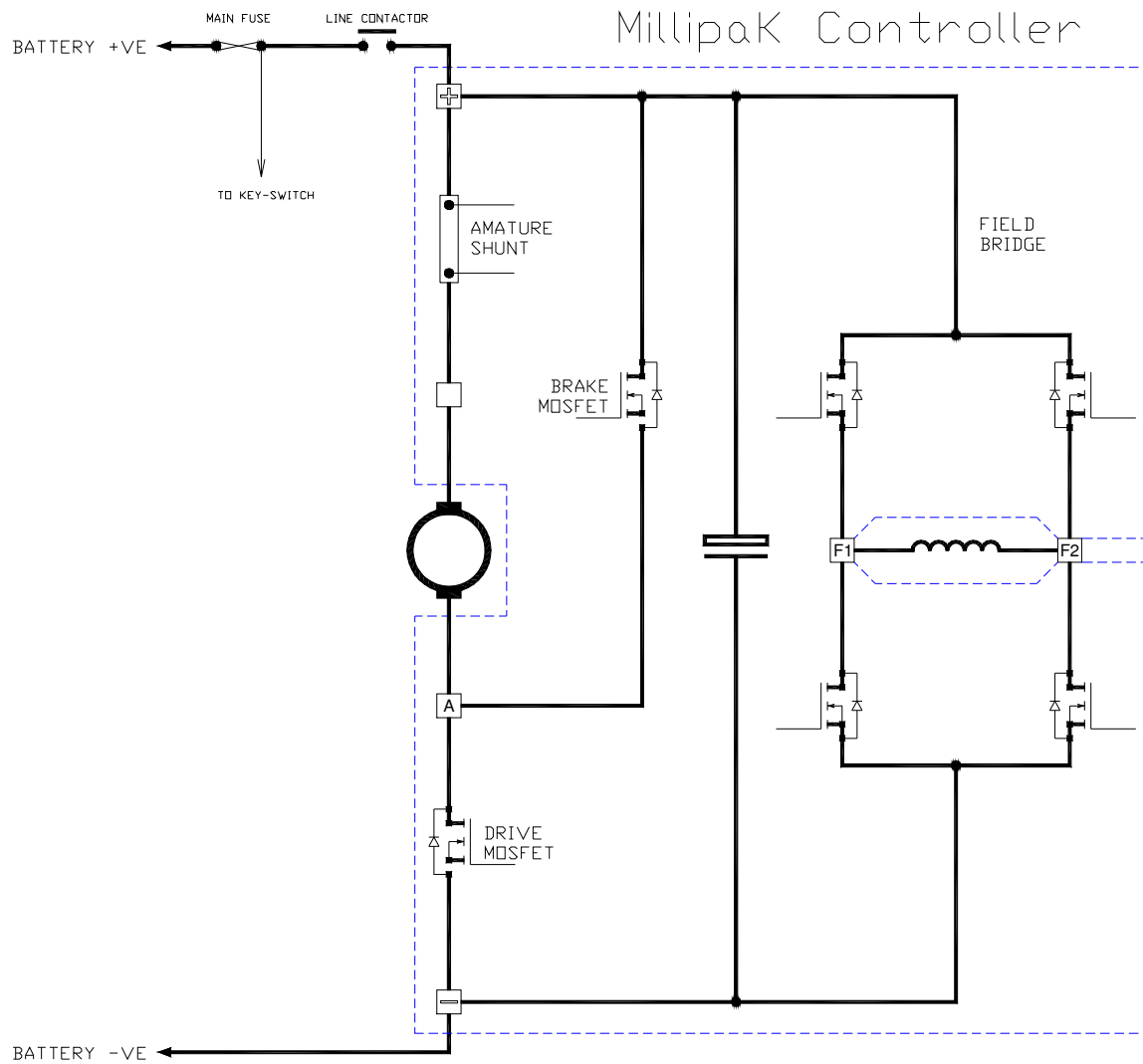
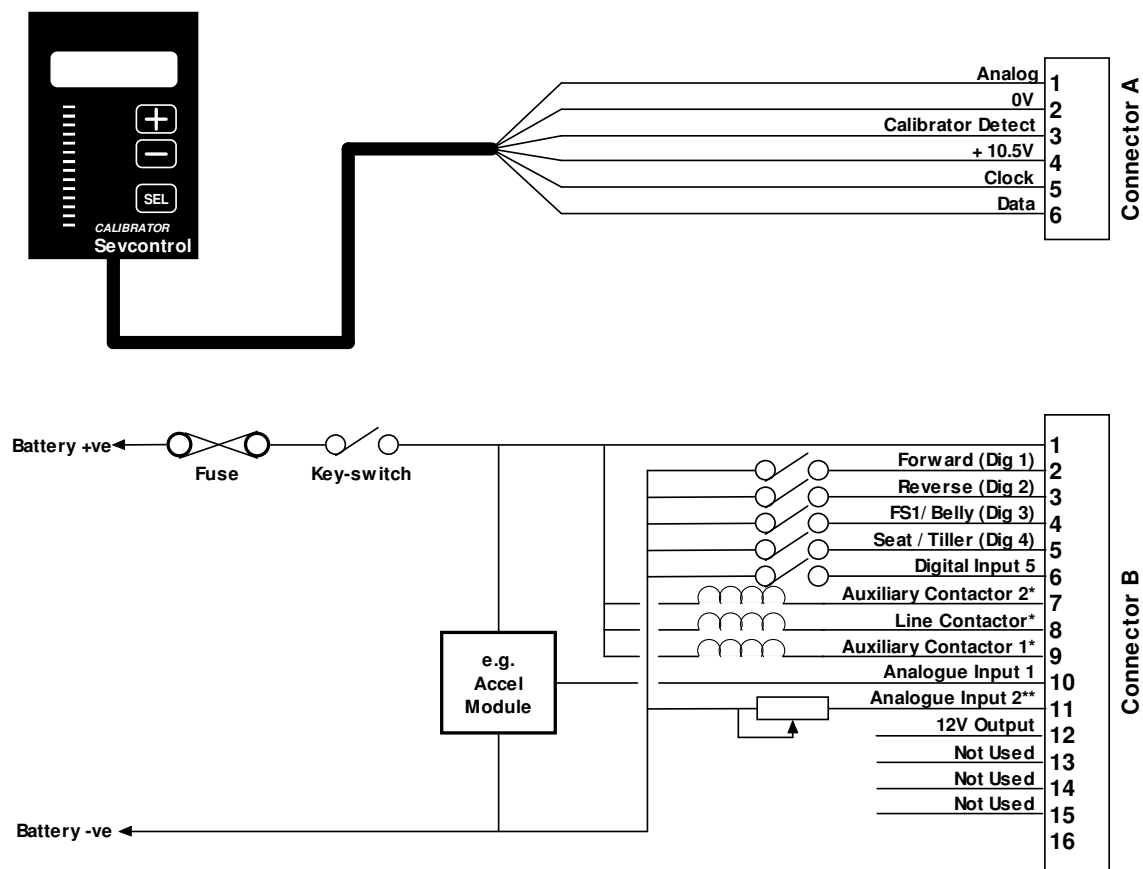


Figure 2: MillipaK SEM Power Wiring

MillipaK Standard HP Light Wiring



NOTES:
*Contactor Coil Suppression fitted internally.
**Analogue Input 2 can also be configured as a digital input.

Figure 3: MillipaK Standard HP Light Wiring

NOTES:

The line and auxiliary contactors are wired to B+, on the switched side of the key-switch.

The second analogue input on pin 11 is also available for use as a digital input. See system configuration section for detail on how to configure the second analogue input as a digital switch input.

Pin 12 on the Standard HP variant is available for 100mA supply, typically used for (but not limited to) accelerator modules.

Pins 13, 14 & 15 are not used.

Pin 16 on the Standard HP variant is used to select FLASH memory program update mode and should normally be left unconnected. However, if it is necessary to reprogram the controller's FLASH memory, pin 16 must be connected to Battery Voltage through the Key switch Line.

PCpaK

PCpaK allows a PC to communicate with an individual MillipaK controller. PCpaK can perform all the functions provided via the Calibrator, along with a number of additional features.

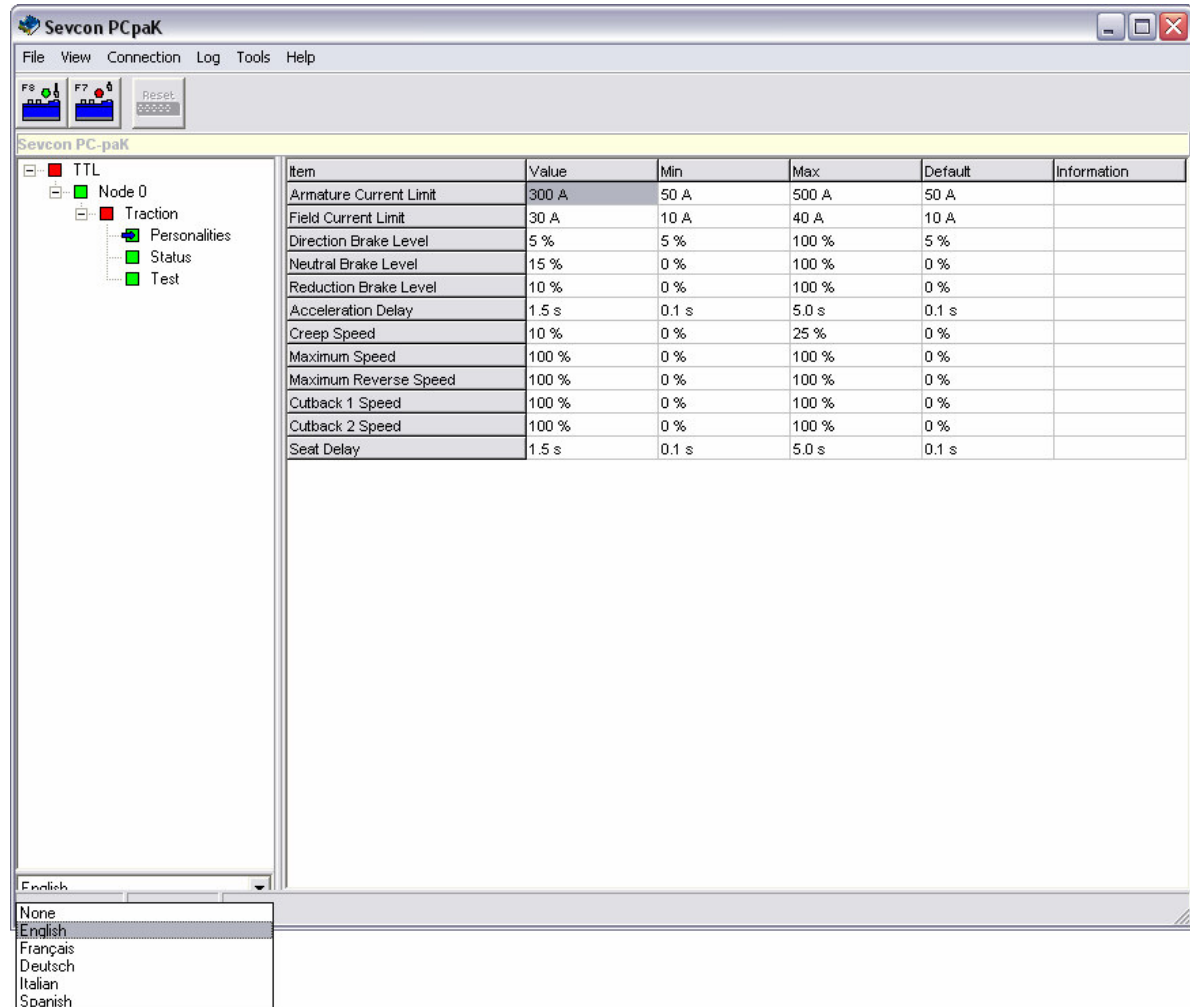


Figure 4: PCpaK Window

PCpaK provides many advantages over using the standard calibrator including the following features:

- Easy to use Windows Explorer style GUI.
- Personalities can be easily modified by typing new values in directly.
- Configuration (personality) setups can be saved and loaded to and from file.
- Previously saved configurations can be quickly downloaded using the Rapid Download wizard.
- Service log analysis.
- Controller status checking.
- Quick viewing of entire controller menu structure.

-
- “Offline” viewing of previously stored configurations. A controller does not need to be connected to view a saved configuration.
 - Flash program capability. PCpaK can reprogram the software in the MillipaK controller.

PCpaK is a powerful tool. Some of the typical uses are:

- Analyzing controllers in the field and recording information, such as personalities, to a file.
- Reprogramming the MillipaK controller software; The MillipaK Controller does not need to be removed from the vehicle for the software to be upgraded.
- As a tool in a production line to program controller software and / or personalities; this allows customers to stock one part number for the Controller hardware and simply reconfigure it when the controller is installed onto the vehicle.

For information about PCpaK, please contact Sevcon Inc.

Calibrator

The Calibrator is a hand-held adjustment unit, which can be used to configure and test the system. The MillipaK is designed to work with the Calibrator currently in use with Sevcon's MOS90 system (see diagram below). The menu structure is shown in the Calibrator Map located near the end of this manual, or can be ordered as a separate document.

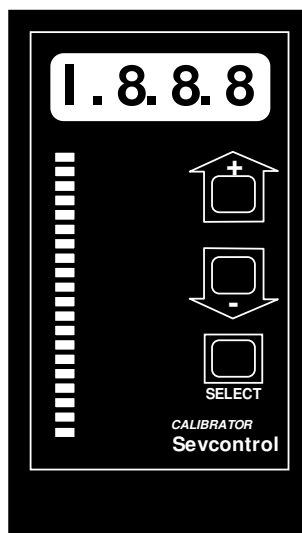


Figure 5: MillipaK Calibrator

Traction Drive Hours Counter

When plugged into the MillipaK, and immediately following power up, the Calibrator handset displays the Traction Drive Hours Counter. Refer to the Traction Drive Hours Counter section for more information on this function.

With no buttons pressed, the display shows the number of minutes (accurate to 0.5 minutes). Pressing the '-' button displays the number of hours under 1000 and pressing the '+' button displays the number of 1000 x hours.

For example, if the hours counter was 12,345 hours, 13 minutes and 40 seconds, with no buttons pressed, the display would show 13.5. If the '-' button were pressed, the display would show 345 (number of hours under 1000) and if the '+' button were pressed, the display would show 12 (number of 1000 x hours).

This is the only time that the hours counter can be viewed. Once the Select button has been pressed to enter the normal calibrator menu structure, it is not possible to return to this point. To view the hours counter again, you must recycle the Key switch.

At this point, the user can enter a password to enable different levels of access to personalities. Refer to the section below on Calibrator Security Levels for more details.

Calibrator Security Levels

The personalities and status items which can be viewed on the Calibrator is restricted using passwords. There are two levels of Calibrator access. These are shown in Table 1.

Access Level	Text	Password	Description
Service	Ser	-	Default. This level is selected when no password or an invalid password is entered. Only items shown in the Calibrator Map with a thick solid border are displayed.
Engineering	Eng	1645	All items could be displayed.

Table 1: Calibrator Security Levels

Note that only items appropriate to the current system configuration are displayed. For example, if none of the switch inputs is configured as a Cutback 1 Speed Switch, then the Cutback 1 Speed personality will not be displayed.

The password can only be entered just after power up, while the Traction Drive Hours Counter is displayed. The '+' and '-' buttons are used to enter the password. The first digit is entered by pressing the '+' button the appropriate number of times (i.e. once to enter 1). The second digit is entered by pressing the '-' button the appropriate number of times (i.e. 6 times to enter 6). The third digit is entered using the '+' button again and the final digit is entered using the '-' button again. Note that when the '+' or '-' buttons are pressed, the display still changes to show hours or 1000 x hours.

After entering the password, press either the '+' button or the SELECT button to initiate verification. If the password has been entered correctly, the text shown in Table 1 appropriate to the required level will be displayed for 1s indicating the password was accepted. If the password was incorrect or no password was entered, the system defaults to Service mode.

After the Security Level has been displayed, the system enters the normal menu structure shown in the Calibrator Map. To change the password level, the Key switch needs to be recycled.

Navigation

The Calibrator uses all three buttons for navigating through the menu structure.

Use the SELECT button to move through the menu structure. When the SELECT button is pressed the next menu item is displayed. The default direction is from left to right, top to bottom.

If the '+' and '-' buttons are held down together, the ID of the currently displayed menu item is shown. For example, if the Armature Current Limit personality was selected, then the ID would be 0.01 (menu 0, item 1). This allows for the exact Calibrator Map position to be identified.

If the '+' and '-' buttons are held down together for more than 3 seconds, the direction through the menu structure is reversed. As a result, when the SELECT button is pressed the direction is from right to left, bottom to top. In this mode, the LED on the Calibrator will flash. If the '+' and '-' buttons are held down together for more than 3 seconds again, the direction reverts back to the initial direction and the Calibrator LED stops flashing.

The SELECT button is used to navigate through most of the menu structure; however, the Test menu (menu 19) is slightly different. To navigate the Test menu, the '+' and '-' buttons are used. The '+' button moves up the Test menu and the '-' button moves back down. Pressing the SELECT button at any time exits the Test menu and moves to the first item in the menu structure (menu item 0.01 - Armature Current Limit).

The items which are displayed depend on the current system configuration and the Security Level.

Adjustments

Menus 0 to 12 are primarily used for configuring the system. All the personalities that the system uses to configure each function are in one of these menus. A brief description of the purpose of each menu is listed below. For more complete descriptions of each personality refer to the appropriate section in this manual.

Menu	Name	Purpose
0	Current Limits	Used to setup maximum currents for motor and some current control properties.
1	Braking Levels	Used to setup braking strength and performance.
2	Accelerator	Used to setup acceleration and deceleration performance and to configure the accelerator input voltage range.
3	Creep Speed	Used to setup creep speed.
4	Bypass	Not used.
5	Maximum Speed	Used to setup the maximum speeds.
6	Cutback 1 Speed	Used to setup the speed for Cutback Speed 1.
7	Cutback 2 Speed	Used to setup the speed for Cutback Speed 2.
8	Motor Setup	Used to setup the Motor parameters.
9	Power Steer Timer	Used to setup the Power Steer timer.
10	Seat Delay	Used to setup the Seat Switch debounce delay.
11	Additional Personalities	Used to setup additional personalities. These are personalities which do not belong in any of the menus shown above, or they are deemed to be unsuitable for modification by service engineers or end users.
12	System Setup	Used to configure the system at a high level. Items to configure the system I/O and performance are located here. It is recommended that items in this menu are configured first, before any of the other personalities. Unlike the personalities in the other menus, changes to items in this menu do not take effect until the Key switch is recycled.

Table 2: Adjustment Menus

Status and Test Information

Menus 13 to 19 are primarily used for providing information about the system. Every parameter which the system measures is located in one of these menus. A brief description of the purpose of each menu is listed below.

Menu	Name	Purpose
13	System Status	If there is a fault active in the system, this menu provides information about what the fault is. Refer to the Diagnostics section for more information.
14	Speed Estimate	Shows the estimated vehicle speed and contains personalities to set up speed limit and speed control (<i>not yet available</i>), and calibrate the speed estimate.
15	System Voltages	Used to display Battery and Capacitor Voltage measurements. The Battery Voltage measurement shows the voltage measured at the Key switch pin (pin 1 on connector B). The Capacitor Voltage measurement shows the voltage measured at the B+ terminal.
16	Motor Voltages	Used to show the voltage measured at the Point A terminal.
17	Motor Currents	Used to show the Armature and Field Current Measurements.
18	Heatsink Temperature	Used to access the Heatsink Temperature measurement and the Maximum Heatsink Temperature log. Refer to the Temperature Monitoring section.
19	Test Menu	Used to access items which allow for testing of all the Analogue and Digital inputs available on connector B. Also displays unit information such as the Software Version, Controller Serial Number and the Personality Checksum. Refer to the appropriate sections for more information on each of these items.

Table 3: Status and Test Information Menus

Configuration

Configuration of the MillipaK controller is divided into two categories – system and performance; each will be discussed in turn.

System Configuration

The MillipaK system configuration items relate to how the MillipaK will interface with connected hardware such as the system battery, vehicle control switches, accelerator and the traction motor.

System Voltage

The system voltage usually refers to the main system supply battery voltage. The controller uses this information to ensure low and high voltage settings are within an appropriate range.

System Voltage Calibrator Menu Reference:			Power Up
			12.15
Minimum	Maximum	Step Size	Default
24v	48v	2v	24v

System I/O Configuration

The digital inputs, analogue inputs and contactor drive outputs available on socket B can be configured in a number of ways to suit various applications. Table 4 shows a range of pre-determined settings which are available to the user and should cover the majority of applications, see below:

Digital I/O Value	Description
1	Ride On vehicle with Speed Cutback 1 and 2 switches and external LED drive.
2	Ride On vehicle with Speed Cutback 1 switch, Handbrake switch and external LED drive.
3	Ride On vehicle with Handbrake switch, Power Steer Trigger switch and Power Steer Contactor.
4	Ride On vehicle with Speed Cutback 1 switch, Power Steer Trigger switch and Power Steer Contactor.
5	Ride On vehicle with Handbrake switch, Pump Trigger switch and Pump Contactor.
6	Ride On vehicle with Handbrake switch, Pump Trigger switch and Pump Contactor.
7	Ride On vehicle with Power Steer Trigger switch, Pump Trigger switch and Power Steer Contactor. Pump Trigger activates Pump Soft Start function.
8	Ride On vehicle with Traction Motor Over temperature switch, Handbrake switch and external LED drive.
9	Ride On vehicle with Power Steer Trigger switch, Footbrake switch and Power Steer Contactor.
10	Ride On vehicle with Speed Cutback 1 and 2 switches, and Buzzer Drive.

Table 4: Description of each Digital I/O configuration

WARNING: Incorrect configuration could cause a vehicle to move unexpectedly.

If your application does not fit any of the above, please contact Sevcon with details of your requirements.

Each of the above configurations allocates the controller I/O as shown below:

Digital Function	Value of Digital I/O Configuration Item									
	1	2	3	4	5	6	7	8	9	10
Forward	B2	B2	B2	B2	B2	B2	B2	B2	B2	B2
Reverse	B3	B3	B3	B3	B3	B3	B3	B3	B3	B3
Belly										
Tiller										
FS1	B4	B4	B4	B4	B4	B4	B4	B4	B4	B4
Seat	B5	B5	B5	B5	B5	B5	B5	B5	B5	B5
Speed Cutback 1	B6	B6		B6		B6				B6
Speed Cutback 2	<i>Bw</i>									<i>Bw</i>
Handbrake		<i>Bw</i>	<i>Bw</i>		<i>Bw</i>			<i>Bw</i>		
Power Steer Trigger			B6	<i>Bw</i>			B6		<i>Bw</i>	
Pump Trigger					B6	<i>Bw</i>	<i>Bw</i>			
High Mast										
Motor Over Temperature								B6		
High Speed										
Quick Pick										
Brake Override Switch										
Footbrake Switch									B6	
Line Contactor	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8
Power Steer Contactor			B9	B9			B9		B9	
Pump Contactor					B9	B9	<i>By</i>			
Electromagnetic Brake										
External LED	B9	B9						B9		
Hours Counter Drive										
Buzzer	<i>By</i>	<i>By</i>	<i>By</i>	<i>By</i>	<i>By</i>	<i>By</i>		<i>By</i>	<i>By</i>	B9

Table 5: Digital Functions

Notes:

1. All vehicles have Forward, Reverse, FS1 and Seat switches and a Line Contactor.
2. Connector pins shown in *italics* depend on the controller variant in use. Table 6 shows which pin is used for each variant:

ID	Actual Pin	
	Standard HP	
Switch Inputs	<i>Bw</i>	B11*
	<i>Bx</i>	N/A**
Contactor Drive Outputs	<i>By</i>	B7

Table 6: Pin Allocations

* B11 can only be used as a digital input if Analogue Input 2 is configured as a digital input.

See below.

** N/A means this input or output is not available on that variant.

Analogue Functions

Analogue Function	Value of Analogue Input Configuration Item			
	1	2	3	4
Accelerator	B10	B11	B10	B10
Digital			B11	
Footbrake				B11

Table 7: Analogue Functions**Notes:**

1. Bx refers to Socket B pin numbers.
2. All vehicles have an Accelerator input.

Table 7 details which analogue functions are configured for each value of the Analogue Input Configuration Item.

Digital Configuration			Power Up
Calibrator Menu Reference:			12.13
Minimum	Maximum	Step Size	Default
1	9	1	As required

Analogue Configuration			Power Up
Calibrator Menu Reference:			12.14
Minimum	Maximum	Step Size	Default
1	4	1	As required

System / Motor Set-up

There are various settings available to the user to tailor the MillipaK controller to specific motors and applications.

Field Control

The MillipaK Regen SEM controller employs a self-tuning control loop to control the field current. To initialize the control loop, the controller needs to know the nominal field resistance and inductance of the motor at 25°C. This information should be available from the motor manufacturer.

Correct setting of these personalities is very important to ensure responsive control of the motor field.

Field Resistance Personality			Power Up
Calibrator Menu Reference:			8.08
Minimum	Maximum	Step Size	Typical Value
0.10mΩ	2.55mΩ	0.01mΩ	As required

Field Inductance Personality			Power Up
Calibrator Menu Reference:			8.09
Minimum	Maximum	Step Size	Typical Value
0.1mH	25.5mH	0.1mH	As required.

Armature / Field Map

NOTE: Read the Important Notes at the end of this section.

Personalities

The Armature-Field map is used to calculate the required Field Current based on the measured Armature Current. **Figure 6** shows how the Field Current is related to the Armature Current.

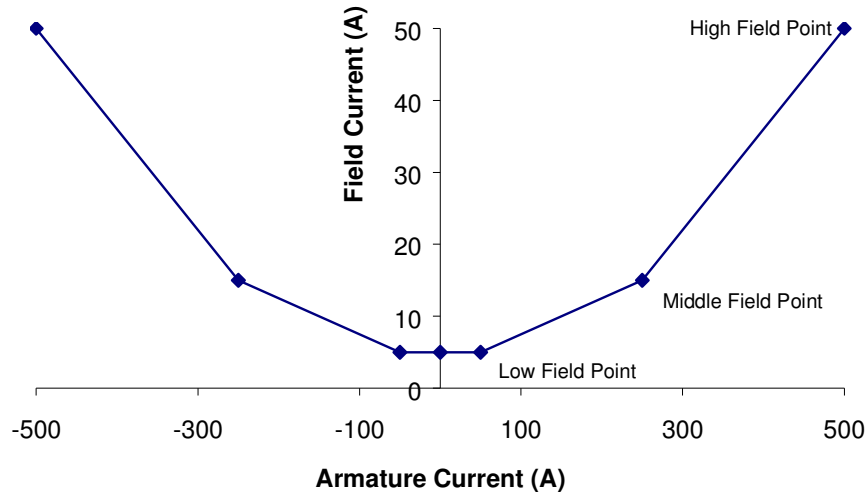


Figure 6: Relationship between Required Field Current and Measured Armature Current

The armature current can be either positive (driving) or negative (braking). The system will automatically generate a negative (braking) current whenever the motor is over-speeding with respect to the accelerator demand.

The system allows 3 points to be defined to specify the minimum field current for a given armature current. Note that the graph is mirrored about the y-axis. Each point shown on the graph is defined by two personalities, one for the field current and one for the armature current.

I_{field} Low personality			Power Up
Calibrator Menu Reference:			8.01
Minimum	Maximum	Step Size	Typical Value
2.0A	Field I_{mid} or 19.75A	0.25A	5.00A

I_{arm} Low personality			Power Up
Calibrator Menu Reference:			8.02
Minimum	Maximum	Step Size	Typical Value
10A	Arm $I_{\text{mid}} - 10\text{A}$	5A	10A

I_{field} Mid personality			Power Up
Calibrator Menu Reference:			8.03
Minimum	Maximum	Step Size	Typical Value
I_{field} Low	I_{field} High	1A	50% of FBR

I_{arm} Mid personality			Power Up
Calibrator Menu Reference:			8.04
Minimum	Maximum	Step Size	Typical Value
I_{arm} Low + 10A	I_{arm} High – 10A	10A	50% of ABR

I_{field} High personality			Power Up
Calibrator Menu Reference:			8.05
Minimum	Maximum	Step Size	Typical Value
I_{field} Mid	FBR	1A	FBR

I_{arm} High personality			Power Up
Calibrator Menu Reference:			8.06
Minimum	Maximum	Step Size	Typical Value
I_{arm} + 10A	ABR	10A	ABR

Maximum Continuous I_{field} personality			Power Up
Calibrator Menu Reference:			8.07
Minimum	Maximum	Step Size	Typical Value
I_{field} Low	I_{field} High	1A	I_{field} Mid

ABR – Armature **B**lock **R**ating

FBR – Field **B**lock **R**ating

The ABR & FBR refer to the controller maximum peak currents.

Setting Up the Armature Field Map

The following notes explain how to set up the Armature / Field Map personalities.

1. The points on the graph (Low, Middle and High Field Points) are used in the first instance to ensure good motor commutation. SEM motors require a minimum field current to be applied for a given armature current to ensure good commutation and to avoid excessive arcing on the armature brushes. The SEM motor manufacturer should be able to supply information on the required field currents for given armature currents.
2. The High Field Point also determines the maximum torque which can be produced by the system.
3. The Low Field Point also determines the top speed of the vehicle. The lower the field current, the higher the vehicle speed. Of course, if the field current is too low, commutation problems can occur, so ensure the field current is not set too low.
4. When setting up each of the points try to keep the field current as high as possible and the armature current as low as possible. Torque is proportional to the armature current multiplied by the field strength, so the same torque can be achieved by reducing the armature current and increasing the field current. This will ensure that maximum system efficiency is achieved.

Maximum Continuous Field Current

The system increases the field current at low vehicle speeds. This improves its ability to provide braking torque down inclines. As the vehicle speed decreases, the field current increases up to the Maximum Continuous Field Current personality. This personality should be set to give the required level of braking down inclines. However, it must not exceed the **maximum continuous field current rating** for the motor or damage to the motor field windings could occur.

IMPORTANT NOTES:

- a. **Setting up the field / armature current map is very important to ensure good system operation; it impacts the maximum torque the vehicle can produce, the vehicle top speed, the vehicle speed when over speeding down an incline and the system efficiency.**
- b. **In order to achieve good over-speed detection at low speeds, the field current is maintained at a higher level at low accelerator demands. It is important to ensure that the field current in the motor does not exceed the continuous rating of the field windings if the system is setup so that the higher field current level could be maintained for long periods of time.**

Armature and Field Current Limit

The armature and field current limit personalities are provided to allow the user to limit the maximum current supplied to the motor to a value lower than the peak rating of the controller.

Armature Current Limit			Immediate
Calibrator Menu Reference:			0.01
Minimum	Maximum	Step Size	Typical Value
50A	ABR	10A	ABR

Field Current Limit			Immediate
Calibrator Menu Reference:			0.02
Minimum	Maximum	Step Size	Typical Value
10A	FBR	1A	FBR

Torque Control and Ramping

The Drive Current Limit Start, Torque Ramp Up Rate and Torque Ramp Down Rate personalities allow the user to configure torque ramps on entry into drive and braking. The Current Limit Multiplier personality allows the user to reduce the available torque at low accelerator demands. These personalities allow the user to setup how the system controls torque.

Controlling Torque on Entry to Drive

When entering drive, particularly after a direction change, the Drive Current Limit Start and Torque Ramp Up Rate personalities are used to control the ramp up of torque. The Drive Current Limit Start personality determines how much instantaneous torque is available at the start of drive and the Torque Ramp Up Rate personality determines how quickly full torque can be achieved. Full torque is achieved more quickly for higher values.

These personalities are used in conjunction with the Direction Braking Exit Level personality (described in the Braking section) to optimize the Direction Braking change over time.

When the system is direction braking, the Direction Braking Exit Level personality will allow braking to finish early when the vehicle is still moving at a reasonable speed. The system then enters drive and ramps up the armature current limit from the Drive Current Limit Start level to the Armature Current Limit personality in the time specified by the Torque Ramp Up Rate personality.

This ramp up acts as a torque ramp and has the effect of completing the braking effort before the vehicle accelerates away in the new direction.

Drive Current Limit Start			Immediate
Calibrator Menu Reference:			0.03
Minimum	Maximum	Step Size	Typical Value
50A	Ia Limit	10A	50A

Ia Limit - Armature Current Limit personality.

Torque Ramp Up Rate			Immediate
Calibrator Menu Reference:			0.05
Minimum	Maximum	Step Size	Typical Value
1%	100%	1%	100%

Controlling Torque on Entry to Braking

The Torque Ramp Down Rate personality is used to setup how quickly full braking torque can be achieved when entering a braking mode like Direction Braking, Neutral Braking, etc.

Full torque is achieved more quickly for higher values.

Torque Ramp Down Rate			Immediate
Calibrator Menu Reference:			0.06
Minimum	Maximum	Step Size	Typical Value
1%	100%	1%	100%

Controlling Torque at Low Speeds

The Current Limit Multiplier personality is used to setup how much torque is available at low accelerator demands. The armature current limit is calculated using the following formula:

$$\text{Armature current limit (A)} = \left(\frac{\text{Accelerator Demand (\%)}}{100} \right) \times \text{Armature I Limit (A)} \times \text{Multiplier}$$

Where:

- Accelerator Demand is the accelerator push.
- Armature I Limit is the Armature Current Limit personality.
- Multiplier is an integer from 1 to 5.

If the Current Limit Multiplier is set to 1, there is a 1:1 relationship between the accelerator demand and the current limit. For example, if the Armature Current Limit personality were 500A and the accelerator push were 10%, the armature current would be limited to 50A.

If the Current Limit Multiplier is set to 5, there is a 1:5 relationship between the accelerator demand and the current limit. For example, if the Armature Current Limit personality was 500A and the accelerator push was 10%, the armature current would be limited to 250A (**the controller armature current limit from item 0.01 will not be modified, meaning that in this example, for an accelerator push greater than 20% the armature current limit will not become greater than 500A!**).

Setting the Current Limit Multiplier to 0 allows for full armature current limit to be achieved regardless of the accelerator demand (in effect, this feature is disabled).

Current Limit Multiplier			Immediate
Calibrator Menu Reference:			0.04
Minimum	Maximum	Step Size	Typical Value
0	5	1	0

Contactor chopping

This feature allows 24 V contactors to be used at all battery voltages 24V - 48V, 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. 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 = 667Hz (Slightly audible).

Typical contactor coil voltage during chopping = 16 volts.

Typical contactor coil voltage when being energized = 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. A setting of 24V provides chopping for 24V coils and lamps without the drop to 16V after 1s.

Chop Select			Power Up
Calibrator Menu Reference:			12.01
Options			Default
OFF	ON	24V	OFF

Accelerator Full / Zero Setting

The accelerator/analogue inputs are flexible in the range of signal sources they can accommodate and can be adjusted to minimize dead-bands and mechanical tolerances. Each analogue input has 2 adjustments associated with it to 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.

Accelerator Zero Voltage			Immediate
Calibrator Menu Reference:			2.03
Minimum	Maximum	Step Size	Typical Value
0.00V	4.50V	0.02V	0.10V

Accelerator Full Voltage			Immediate
Calibrator Menu Reference:			2.04
Minimum	Maximum	Step Size	Typical Value
0.00V	4.50V	0.02V	3.50V

Note that a 6 flash fault will occur if the full and zero levels are set within 0.50V of each other.

The PWM demand will vary between the Creep level and Maximum Speed level as the accelerator voltage varies between “Accelerator Zero” and “Accelerator Full”.

Performance

Various parameters may be adjusted to tailor the performance of the vehicle to customer requirements.

Acceleration Delay

This is an adjustable delay to ramp up the pulsing from 0% on to 100% on, and can be used to ensure smooth acceleration.

Acceleration Delay			Immediate
Calibrator Menu Reference:			2.01
Minimum	Maximum	Step Size	Typical Value
0.1s	5.0s	0.1s	1.5s

Deceleration Delay

This is an adjustable delay to ramp down the pulsing from 100% on to 0% on, and can be used to provide a smooth reduction of power to the motor.

On this type of system, ramping down the pulsing can also initiate braking. This is known as Reduction Braking. The faster the ramp down rate, the more braking is produced. The braking armature current is, however, limited by the Reduction Braking Level personality. If the Reduction Braking Level personality is set to 0%, the braking armature current is limited by the Armature Current Limit personality.

Deceleration Delay			Immediate
Calibrator Menu Reference:			2.02
Minimum	Maximum	Step Size	Typical Value
0.1s	10.0s	0.1s	2.5s

Reduction braking level			Immediate
Calibrator Menu Reference:			1.04
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	0%

Control Mode

The method of motor control may be switched between Torque Control, Torque Control with Speed Limit and Closed Loop Speed control (***Closed Loop Speed Control not yet available***).

Control Mode		Power Up
Calibrator Menu Reference:		12.03
Options		Default
Torque	Speed Limit	Torque

Torque Control

In Torque Control mode, the voltage applied across the motor armature is proportional to the accelerator demand. When climbing an incline, the operator will need to increase the accelerator demand to maintain the speed. When descending an incline, there will be no maximum speed limit applied.

Torque Control with Speed Limit

This mode is the same as Torque Control, except a maximum speed limit is applied. The controller will never allow the speed to exceed the specified maximum.

Closed Loop Speed Control (***not yet available***)

In Closed Loop Speed Control mode, the speed of the vehicle is controlled to the speed demand from the operator. The controller will increase or decrease power to the motor or will initiate braking to maintain the target speed.

Configuring the system for Speed Control (***not yet available***) or Speed Limit

The following procedure should be applied when configuring a system for Closed Loop Speed Control and Speed Limit mode.

1. Set up all other motor control parameters first. Personalities such as Current Limits, Acceleration and Deceleration Delays, Motor Setup table, Field Control, etc can all have an effect on speed control and limit. Ensure these are setup first with the control mode set to Torque Control.
2. Calibrate the speed estimate. See below.
3. Setup the PI control loop. See below.

Calibrating the Speed Estimate

The MillipaK Regen SEM Controller does not require a speed encoder. It estimates speed by measuring certain motor parameters and applying an estimation algorithm. The accuracy of the speed estimate has a direct effect on the accuracy of the speed control (***not yet available***) and speed limit. It is important that the speed estimate is correctly setup before tuning the speed control and speed limit control loops.

Use the following procedure:

1. Put the system in Torque Control.
2. Set the Armature Resistance personality to the nominal armature resistance for the motor at 25°C.

Armature Resistance			Immediate
Calibrator Menu Reference:			8.07
Minimum	Maximum	Step Size	Typical Value
0mΩ	100mΩ	1mΩ	As required.

3. Drive the vehicle at top speed on a flat surface and monitor the estimated speed on PCpaK (in Status Menu) or on the calibrator (Item 14.01).
4. Modify the Speed Estimate Calibration personality using PCpaK (in Personalities Menu) or the calibrator (Item 14.04) until the speed estimate reads as 100% when the vehicle speed is at its maximum on the flat.

Speed Estimate Calibration			Immediate
Calibrator Menu Reference:			14.04
Minimum	Maximum	Step Size	Typical Value
0	200	1	As required.

Setting Up the Control Loop.

The MillipaK Regen SEM Controller uses PI Control Loops to control both speed control (***not yet available***) and speed limit. The control loop gains need to be set up for the loop to operate correctly.

The control loop gains are in the Personalities menu on PCpaK or in items 14.02 and 14.03 on the calibrator.

Proportional Gain			Immediate
Calibrator Menu Reference:			14.02
Minimum	Maximum	Step Size	Typical Value
0	255	1	As required.

Integral Gain			Immediate
Calibrator Menu Reference:			14.03
Minimum	Maximum	Step Size	Typical Value
0	255	1	As required.

The following procedure can be used as a guide to setting initial values for the gains:

- Set the integral gain to 0 so that the loop only has a proportional part.
- Set the proportional gain to that the loop can set the output to achieve about 80% of the set point.
- Start increasing the integral gain until the set point is achieved in an acceptable time.

Unfortunately, it is not always that straight forward. When setting the gains, take note of the following points:

- If the proportional or integral gains are too small the system will be unresponsive.
- If the proportional or integral gains are too large the system will be unstable (i.e. some oscillation will be seen).
- In order to keep the PI control loop as stable as possible, the gains should be kept as low as possible.

Braking

Braking can be initiated in one of 3 ways:

- (i) **Direction Braking.** Initiated when the direction switch inputs are reversed during drive. i.e., Reverse is selected when driving in Forward or Forward is selected when driving in Reverse.
- (ii) **Footbrake Braking.** Initiated when the operator depresses the Footbrake pedal and a footbrake input is configured. See section below for more information about setting up and configuring the system for Footbraking.
- (iii) **Neutral braking.** Initiated when the vehicle is put into neutral during drive and neutral braking level is greater than 0%.
 - For a neutral braking level setting of 0%, the braking strength is determined by the Deceleration Delay personality setting (fixed time).
 - For neutral braking level settings other than 0%, the braking strength is determined by the Neutral Braking Level personality (fixed torque).
- (iv) **Reduction braking.** Initiated when the operator reduces accelerator demand, but does not select neutral. See the Deceleration Delay section for more information.

Braking Levels

Each Braking Type has its own personality for setting the required braking level. These are shown below:

Direction braking level			Immediate
Calibrator Menu Reference:			1.01
Minimum	Maximum	Step Size	Typical Value
5%	100%	1%	75%

Neutral braking level			Immediate
Calibrator Menu Reference:			1.02
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	10%

Footbrake braking level			Immediate
Calibrator Menu Reference:			1.03
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	0%

Direction Braking Exit Level			Immediate
Calibrator Menu Reference:			1.05
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	0%

The three braking levels for direction, neutral and footbraking are used to determine the strength of the braking. Setting the level to 0% disables braking (Note: Direction Braking cannot be disabled), 1% sets the braking strength to minimum (weakest braking) and 100% sets the braking strength to maximum (strongest braking).

Direction Braking also has an additional personality used to setup the system to exit braking early. This personality, Direction Braking Exit Level, is used to increase the exit level and is specified as a percentage, where 0% causes the system to use the same exit level as Neutral and Footbraking. Refer to the current limit section for a more details on how to use this personality.

Footbraking

Footbraking can be initiated in one of two ways:

- Via an analogue input configured as a Footbrake Pot. Using a potentiometer allows the operator to vary the amount of braking they want. See below.
- Via a digital input configured as a Footbrake switch. When the switch is active, the system will brake at the footbrake level.

Footbrake Pot

If the system is configured to use a Footbrake Pot, then the system will allow the operator to vary the amount of footbraking depending on the position of the footbrake pedal. Similar to the Accelerator input there are 2 personalities which can be used to setup the input voltage range of the Footbrake Pot.

Footbrake Zero Voltage			Immediate
Calibrator Menu Reference:			11.08
Minimum	Maximum	Step Size	Typical Value
0.00V	4.50V	0.02V	0.10V

Footbrake Full Voltage			Immediate
Calibrator Menu Reference:			11.09
Minimum	Maximum	Step Size	Typical Value
0.00V	4.50V	0.02V	3.50V

As the input voltage varies from the Zero level to the Full level, the footbrake demand varies from 0% to 100%. When the footbrake demand is at 0%, there is no footbraking is disabled. As the footbrake demand increases from 1% to 100%, the braking level applied by the system increases from 50% of the Footbrake Level personality to 100% of the Footbrake Level personality.

For example, assume the system is configured to have a footbrake pot and the Footbrake Level personality is set to 60%. If the operator has not depressed the footbrake pedal, then the voltage into the controller will be outside of the Footbrake Zero Level personality and the footbrake demand will be 0%. There will be no footbraking.

If the operator starts to press the footbrake pedal, then the footbrake demand will increase. When the demand increases above 0% the system will start braking and will set the braking effort according to the following formula:

$$\text{braking effort} = \left(\frac{\left(\frac{\text{footbrake demand}}{2} \right) + 50}{100} \right) \times \text{footbrake level personality}$$

So, for this example, at 1% demand the braking effort would be

$$\text{braking effort} = \left(\frac{\left(\frac{1}{2} \right) + 50}{100} \right) \times 60$$

$$= 30\%$$

And at 75% demand the braking effort would be

$$\text{braking effort} = \left(\frac{\left(\frac{75}{2} \right) + 50}{100} \right) \times 60$$

$$= 52.5\%$$

Footbrake Priority

Footbrake priority can be set to drive or brake and this determines the controller action in the case of the accelerator and footbrake pedal both being active at the same time.

Footbrake Priority		Power Up
Calibrator Menu Reference:		12.11
Options		Default
Drive	Brake	Drive

Creep Speed

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

Creep Speed			Immediate
Calibrator Menu Reference:			3.01
Minimum	Maximum	Step Size	Typical Value
0%	25%	1%	0%

Maximum Speed

In Torque Control mode this adjustment limits the maximum applied voltage to the armature. In Speed Limit mode, this adjustment sets the maximum speed limit and in Closed Loop Speed Control mode (*not yet available*), this adjustment sets the speed which is demanded when full accelerator is applied.

Maximum Speed			Immediate
Calibrator Menu Reference:			5.01
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	100%

Reverse Speed Limit

An adjustable reverse speed limit can be setup on the system. If the reverse speed limit function has been enabled, the reverse speed is limited according to the maximum reverse speed personality.

In Torque Control mode this adjustment limits the applied voltage to the armature. In Speed Limit and Speed Control mode (***not yet available***), this adjustment sets an actual speed limit.

Maximum Reverse Speed			Immediate
Calibrator Menu Reference:			5.02
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	50%

Reverse Speed Enable		Power Up
Calibrator Menu Reference:		12.05
Options		Default
Off	On	Off

Accelerator Characteristics

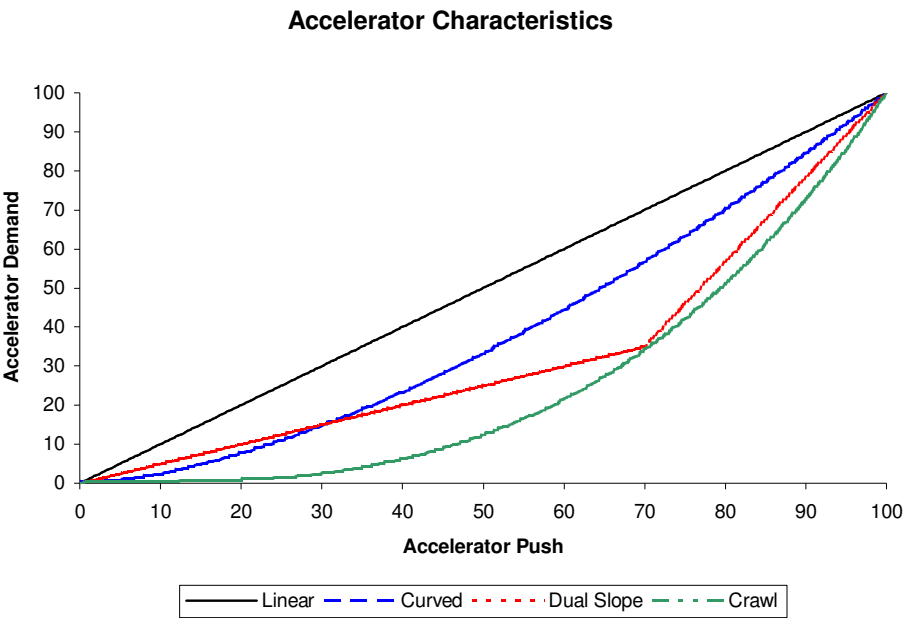


Figure 7: Accelerator Characteristics

Accelerator Characteristics				Power Up
Calibrator Menu Reference:				12.09
Options				Default
Linear	Curved	2*Slope	Crawl	Linear

This function is used to vary how much speed is demanded depending on the accelerator position. Setting either Curved, Dual Slope or Crawl gives a smaller change in speed for large changes in accelerator position and is useful for low speed maneuvering.

Features

The MillipaK controller has several features designed to offer the user maximum flexibility, safety and performance whilst ensuring the controller is protected against adverse or harsh driving conditions. These features can be split into three categories – standard controller features, safety features and controller protection features.

Standard Controller Features

The following section details the standard features found on a MillipaK controller.

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.

The following triggers are available and configurable for power steer:

Power Steer Trigger Configuration Item	Triggers		
	FS1 switch	Fwd or Rev switch	Seat switch
0	No	No	No
1	Yes	No	No
2	No	Yes	No
3	Yes	Yes	No
4	No	No	Yes
5	Yes	No	Yes
6	No	Yes	Yes
7	Yes	Yes	Yes

Table 8: Internal Power Steer Triggers

The software also monitors the motor for movement (if the Anti-Roll-Off feature is enabled) and activates the power steer driver accordingly.

Power Steer Personalities:

Power Steer Timer			Immediate
Calibrator Menu Reference:			9.01
Minimum	Maximum	Step Size	Typical Value
0S	60S	1S	2S

Power Steer Trigger			Power On
Calibrator Menu Reference:			12.10
Minimum	Maximum	Step Size	Default
0	7	1	0

See also contactor drive output configuration (System/Digital IO).

Pump Contactor

A contactor drive is available to control a separate Pump motor. To use this feature, both the Pump Trigger switch and Pump Contactor drive must be configured.

The Pump Contactor drive will activate when the Pump Trigger switch is active and will deactivate 0.5s after the Pump Trigger switch is deactivated. The 0.5s delay is used to debounce the Pump Trigger switch.

Hours Counter Drive

To use this feature, the Hours Counter Drive output must be configured.

The contactor drive output on pin 7 on customer connector B has an internal pull up resistor. This allows it to be used to drive an external Hours Counter.

The output is low when the controller is not pulsing. The Hours Counter should not be counting.

The output is high when the controller is pulsing. The Hours Counter should be counting.

Contactor Chopping is not applied to this output.

External LED Drive

To use this feature, the External LED Drive output must be configured.

This output is pulsed at the same rate as the Controller LED. It can be used to control a fault lamp on the vehicle dash board. Any flash faults shown on the LED can also be shown via this output.

If Contactor Chopping is set to On or 24V, the output will only pulse at 24V to prevent the lamp brightness from varying when other contactor outputs are activated.

Traction Motor Over-Temperature Input

To use this feature, the Traction Motor Over-Temperature Input must be configured. This feature can be used to reduce the power output from the controller if the Traction Motor is over heating.

If the Traction Motor Over-Temperature Input is active, the armature current limit is reduced to 1/3rd of the Armature Current Limit personality.

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.

Seat Delay			Immediate
Calibrator Menu Reference:			10.01
Minimum	Maximum	Step Size	Typical Value
0.1S	5.0S	0.1S	5.0S

Seat Cuts Pump		Power On
Calibrator Menu Reference:		12.04
Options		Typical Value
OFF	ON	OFF

Handbrake Switch

An input is provided for the connection of a handbrake switch, which if operated will disable armature pulsing but leave a low level field current to effect a minimum roll back hill start when drive is selected and the handbrake is released.

Cutback speeds

There are 2 cutback switch inputs as standard. Each one has an associated personality to adjust the maximum speed limit on when the cutback function is active. When both cutback functions are active together, the lower speed limit is selected. The cutback speed inputs are normally closed so that a wire off type fault or bad connection initiates a lower speed.

Cutback Speed 1			Immediate
Calibrator Menu Reference:			6.01
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	100%

Cutback Speed 2			Immediate
Calibrator Menu Reference:			7.01
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	100%

Traction Drive Hours Meter

The MillipaK maintains a log of the number of hours during which the controller is providing Traction functionality. The Traction Drive Hours Meter runs whenever the vehicle is driving or braking. The current number of logged Traction hours can be viewed using the Calibrator. Refer to the Calibrator section for more information.

Personality Checksum

As you can see from this Manual and the Calibrator Map, the MillipaK employs quite a few personalities to give the user as much flexibility as possible in setting up their system. After the personalities have been setup to give the desired functionality and performance, most customers will request the same setup for each subsequent controller they purchase.

If you wanted to check that a controller had the correct personalities, it is very tedious and time consuming to check each individual personality in turn. To remove the need for this, the system calculates a checksum value based on the value of each of the personalities in its memory. The checksum value is simply a number between 0 and 255 which is calculated by passing all the personality values through an algorithm.

The Personality Checksum will be same on every unit (with the same number of personalities) for the same set of personality values. This can be used to instantly confirm that all the personalities are correct. The Personality Checksum is located in the Test menu.

Alarm Buzzer

The Buzzer function is used to drive a warning buzzer when the vehicle is moving or in a fault condition. When a Buzzer output is configured, the following options can be selected in the Setup Menu:

- Off
- Reverse / Roll Off
- Motion

If **Off** is selected, the buzzer output will remain off.

If **Reverse / Roll Off** is selected, the buzzer output will do one of the following:

- If the reverse switch is closed or the vehicle is moving in reverse, the buzzer output will activate continuously.
- If the controller is applying Anti-Roll Off braking, the buzzer output will be pulsed with an on time of 0.5s and an off time of 1.0s.
- If the controller is in a fault condition which would prevent drive, the buzzer output will be pulsed with an on time of 1.0s and an off time of 1.0s.

If **Motion** is selected, the buzzer output will do all of the actions described for Reverse / Roll Off, and, in addition, the buzzer output will also activate continuously when the forward switch is closed or the vehicle is moving in forward. Basically, the Buzzer Output is active whenever the vehicle is moving.

Alarm Buzzer			Power Up
Calibrator Menu Reference:			12.12
	Options		Default
Off	Rol	All	Rol

Line Contactor Drop out

A configurable option is available where the line contactor is opened (dropped out) if no drive activity has occurred for a period exceeding the Line Contactor Dropout Timer personality. If drive operation is selected once the line has been opened, then it will be closed again so that drive operation can occur. Line contactor dropout operation can be enabled or disabled in the setup menu.

Line Contactor Drop Out		Power Up
Calibrator Menu Reference:		12.08
Options		Default
OFF	ON	OFF

Line Contactor Drop Out Timer			Immediate
Calibrator Menu Reference:			11.02
Minimum	Maximum	Step Size	Typical Value
0s	60s	1s	10s

NOTE: If anti-roll off detection is required, a high power, low resistance resistor needs to be fitted across the line contactor to allow the controller to maintain enough field flux to detect vehicle movement. The resistor value should be large enough to ensure that the controller does not detect the resistor as a short circuit across the line contactor at power up, but small enough to allow enough current to flow to keep a minimum field flux established.

Safety Features

The features listed in this section are designed with the safety of the operator in mind.

Start Up Sequence

At power up or after a fault condition, the Direction and FS1 switches must be in the neutral position simultaneously at least once before drive can be selected. This is a safety feature to help prevent unexpected movement.

Alternatively, the system may be programmed to only check FS1 at power up. This option is programmable:

Direction Switch Checking		Power Up
Calibrator Menu Reference:		12.07
Options		Default
OFF	ON	ON

FS1 Recycle

On some vehicles, such as Golf Cars, it is desirable to force the operator to remove accelerator demand before allowing the vehicle to drive in the opposite direction from that it has been traveling in. This feature is implemented as an option.

FS1 Recycle		Power Up
Calibrator Menu Reference:		12.06
Options		Default
OFF	ON	OFF

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 the SRO delay). Any other sequence will not allow drive. Drive will be inhibited if FS1 is active for more than the SRO delay with no direction selected. In this case the FS1 will need to be recycled.

Static Return to Off		Power Up
Calibrator Menu Reference:		12.02
Options		Default
OFF	ON	OFF

SRO Delay			Immediate
Calibrator Menu Reference:			11.03
Minimum	Maximum	Step Size	Typical Value
0s	5s	1s	2s

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.

Anti-Rolloff

This feature is designed so that if a vehicle is powered up, without its handbrake applied, any non-drive condition on a gradient results in the vehicle braking slowly, in a controlled fashion, down a ramp, without running away.

The Roll-Off Electro-brake option may be set so that the Electro-brake (if fitted & configured) is applied (brakes on) when Roll-Off is detected.

The Roll-Off strength is determined by the value of the Roll-Off Speed personality. 0% disables Roll-Off completely, 1% will apply maximum braking effort and 100% will apply minimum braking effort.

Roll-Off Speed			Immediate
Calibrator Menu Reference:			11.01
Minimum	Maximum	Step Size	Typical Value
0%	100%	1%	60%

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 the contactors.

Controller Protection Features

There are several in built features which are designed to protect the MillipaK controller from damage due to excessive load currents, voltages and prolonged periods of high demand.

Temperature Monitoring

If the temperature of either power frame exceeds 75°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 75°C. The thermal cutback ensures that the maximum heatsink temperature is limited to 90°C (See Figure 8). 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.

Thermal Cutback Characteristic

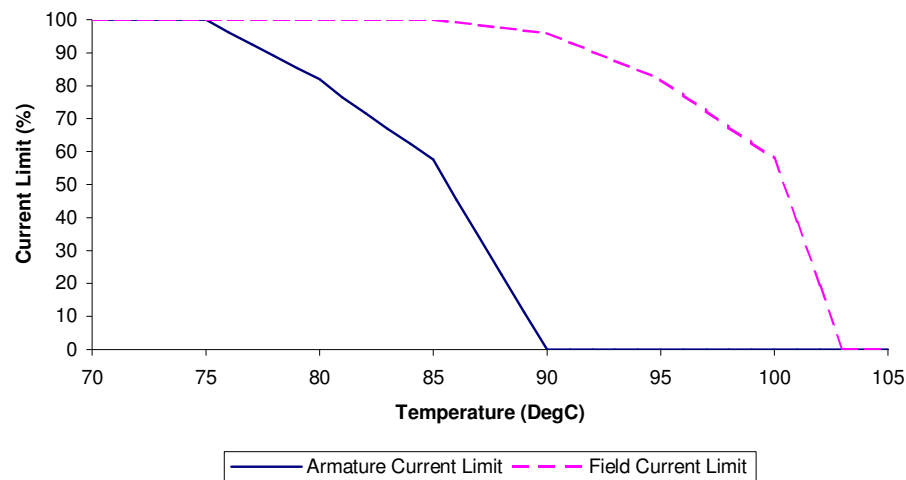


Figure 8: Armature Thermal Cutback Characteristic

Maximum Temperature Logging

The system maintains a log of the maximum heatsink temperature measured by the controller. The Maximum Temperature logged is displayed on the Calibrator next to Heatsink Temperature measurement.

To reset the log select the Maximum Temperature Log reset item on the Calibrator. It will display 'Log'. Press the '+' button and the display will show 'Clr' for 2s before returning back to 'Log'. The maximum temperature has now been reset to the current heatsink temperature.

Dynamic Power Monitoring

During periods of high current usage the power components of the controller produce considerable heat. The controller monitors the power supplied over time and can reduce the power output if the maximum controller rating is exceeded.

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.

The "Safe Operating Area" is a characteristic of the MOSFETs and Freewheel Diodes which make up the power-frame.

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

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 Low Voltage Start level. The current will be ramped down to 0, and a 7 flash fault will be displayed by the **Diagnostic LED** mounted on the controller if the average battery voltage falls below the Low Voltage Cutout level.

To protect the controller from over-voltage (prolonged regen braking could create such a situation), regen braking will be reduced when the average battery voltage reaches the High Voltage Start level. If the average battery voltage exceeds the High Voltage Cutout level in braking, the controller will exhibit a drive inhibit fault accompanied by a 7 flash code displayed by the **Diagnostic LED**. The system will still allow neutral braking to prevent a runaway situation.

Under any other circumstances, if the battery voltage exceeds the High Voltage Cutout level the controller will exhibit a drive inhibit fault accompanied by a 7 flash code displayed by the **Diagnostic LED**. If the line contactor is open when the condition occurs, it will stay open; this protects against incorrect battery connection.

The following calibrator menu items are used to set these values.

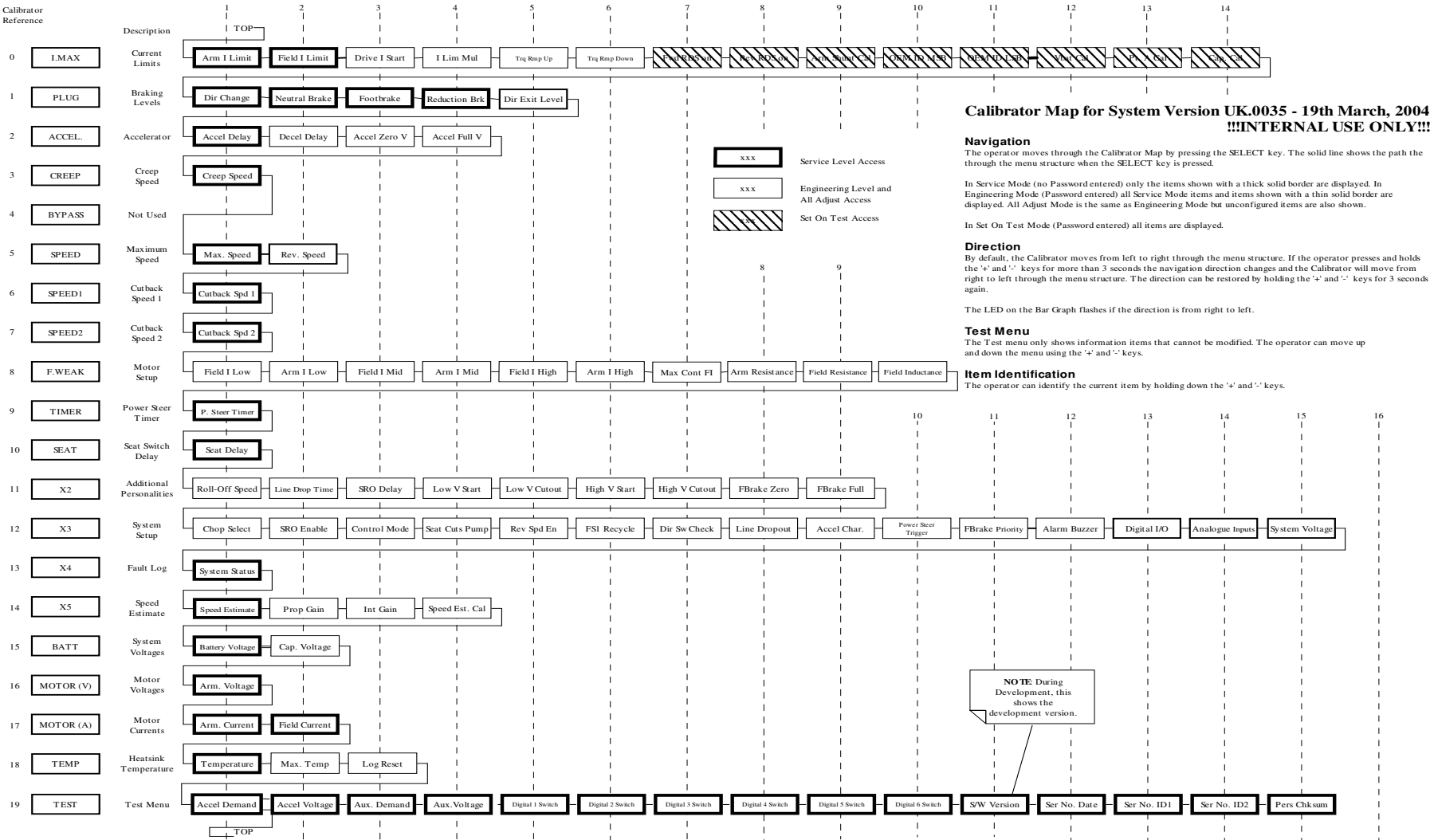
Low Voltage Start			Immediate
Calibrator Menu Reference:			11.04
Minimum	Maximum	Step Size	Typical Value
Low V Cutout	System Voltage	0.5V	18.0V

Low Voltage Cutout			Immediate
Calibrator Menu Reference:			11.05
Minimum	Maximum	Step Size	Typical Value
14.5V	Low V Start	0.5V	16.0V

High Voltage Start			Immediate
Calibrator Menu Reference:			11.06
Minimum	Maximum	Step Size	Typical Value
System Voltage	High V Cutout	0.5V	High V Cutout

High Voltage Cutout			Immediate
Calibrator Menu Reference:			11.07
Minimum	Maximum	Step Size	Typical Value
High V Start	50.0V or 69.0V	0.5V	50.0V or 69.0V

The maximum High Voltage Cutout level depends on the System Voltage personality setting. For System Voltage settings of 36V or lower, the maximum High Voltage Cutout level allowed is 50.0V. For System Voltage settings greater than 36V, the maximum High Voltage Cutout level allowed is 69.0V.



Commissioning Checklist

- Controller Mounted on suitable, flat heatsink, with appropriate heatsink compound?
- Power wiring checked, shortest routes taken where possible?
- Light wiring checked; use calibrator to verify controller correct switch operation.
- Accelerator set-up and checked 0 – 100%?
- Personalities all set, checked and record filled out?

Personality Record

Personality		New Setting	Range	
			Minimum	Maximum
0.01	Armature Current Limit (A)		50A	ABR
0.02	Field Current Limit (A)		10A	FBR
0.03	Drive I Limit Start (A)		50A	Armature I Limit
0.04	I Limit Multiplier		0	5
0.05	Torque Ramp Up Rate (%)		0%	100%
0.06	Torque Ramp Down Rate (%)		0%	100%
1.01	Direction Change Level (%)		5%	100%
1.02	Neutral Brake (%)		0%	100%
1.03	Footbrake Level (%)		0%	100%
1.04	Reduction Brake Level (%)		0%	100%
1.05	Direction Exit Level (%)		0%	100%
2.01	Acceleration Delay (s)		0.1s	5.0s
2.02	Deceleration Delay (s)		0.1s	10.0s
2.03	Accelerator Zero Voltage (v)		0.00V	4.50V
2.04	Accelerator Full Voltage (v)		0.00V	4.50V
3.01	Creep Speed (%)		0%	25%
5.01	Max Speed (%)		0%	100%
5.02	Max Reverse Speed (%)		0%	100%
6.01	Cutback Speed 1 (%)		0%	100%
7.01	Cutback Speed 2 (%)		0%	100%
8.01	Field I Low (A)		2.00A	I _f Mid or 19.75A
8.02	Armature I Low (A)		10A	Arm I Mid – 10A
8.03	Field I Mid (A)		Field I Low	Field I High
8.04	Armature I Mid (A)		Arm I Low + 10A	Arm I High – 10A
8.05	Field I High (A)		Field I Mid	FBR
8.06	Armature I High (A)		Arm I Mid + 10A	ABR
8.07	Max Continuous Field I (A)		Field I Low	Field I High
8.08	Armature Resistance (mOhms)		0mΩ	100mΩ
8.09	Field Resistance (Ohms)		0.10Ω	2.55Ω
8.10	Field Inductance (mH)		0.1mH	25.5mH
9.01	P. Steer Timer (s)		0s	60s
10.01	Seat Delay (s)		0.1s	5.0s
11.01	Roll-off Speed (%)		0%	100%
11.02	Line Cont. Dropout Timer (s)		0s	60s
11.03	SRO Delay (s)		0s	5s
11.04	Low Voltage Start (v)		Low V Cutout	System Voltage
11.05	Low Voltage Cutout (v)		14.5V	Low V Start
11.06	High Voltage Start (v)		System Voltage	High V Cutout
11.07	High Voltage Cutout (v)		High V Start	50.0V or 69.0V

Personality		New Setting	Range	
			Minimum	Maximum
11.08	Footbrake Zero Voltage (v)		0.00V	4.50V
11.09	Footbrake Full Voltage (v)		0.00V	4.50V
12.01	Chop Select		OFF/ON/24V	
12.02	SRO Enable		OFF/ON	
12.03	Control Mode		TORQUE/SPEED LIMIT	
12.04	Seat Cuts Pump		OFF/ON	
12.05	Reverse Speed Limit Enable		OFF/ON	
12.06	FS1 Recycle on Direction		OFF/ON	
12.07	Dir. Switch Checking		OFF/ON	
12.08	Line Contactor Dropout		OFF/ON	
12.09	Accelerator Characteristic		LINEAR/CURVED/2*SLOPE/CRAWL	
12.10	Power Steer Trigger		FS1/SEAT/DIRECTION	
12.11	Footbrake Priority		DRIVE/FOOTBRAKE	
12.12	Buzzer Configuration		OFF/ROLLOFF/MOTION	
12.13	Digital I/O Configuration		1	9
12.14	Analogue Input		1	4
12.15	System Voltage (v)		24V	48V
14.02	Proportional Gain		0	255
14.03	Integral Gain		0	255

Table 9: Personality Record

Fault Finding

The MillipaK controller includes a number of features designed to help the user track down operational faults, wiring faults or internal controller faults.

The **Diagnostic LED** mounted next to the calibrator connectors on the front of the controller serves as a simple diagnostic tool as explained below:

ON	No fault, normal condition
OFF	Internal controller fault
1 flash	Personality out of range
2 flashes	Illegal start condition (Traction)
3 flashes	MOSFET Short Circuit
4 flashes	Contact fault, Motor Open Circuit or Field Open Circuit
5 flashes	Not used
6 flashes	Accelerator wire off fault
7 flashes	Low or High battery voltage, High Capacitor voltage
8 flashes	Over temperature or I ² t cutback

Table 10: Flash Fault Descriptions

In addition to the LED indication a more detailed description of any faults detected may be found by using the calibrator. Menu item number 13.01 gives a code which corresponds to the following detected faults:

ID	Fault	Description	Flash Fault
0	System OK		On
1	Thermal Cutback	Maximum power available to the motor has been reduced due to excessive Heat sink temperature.	8
2	I ² t Current Limit Cutback	Maximum power available to the motor has been reduced by the I ² t Current Limit Cutback function.	8
3	Accelerator Wire Off	Input wire from accelerator has been disconnected.	6
4	Accelerator Pressed at Power Up	Accelerator pedal pressed at power up	6
5	Belly Fault	The Belly switch function has occurred	2
6	Seat Fault	Drive selected and no seat switch closed.	2
7	FS1 Recycle Fault	FS1 switch needs to be recycled after a direction change	2
8	SRO Fault	Direction switch selected	2

		for greater than 2 seconds with FS1 open.	
9	Two Direction Fault	Two directions selected together.	2
10	Sequence Fault	Direction or FS1 switch closed at power up.	2
11	Low Battery Fault	Battery voltage is too low.	7
12	High Battery Fault	Battery voltage is too high.	7
13	High Battery Fault with Line Contactor Open	Battery voltage is too high before the line contactor is closed	7
14	Configuration Range Fault	A personality is out of range.	1
15	Configuration CRC Fault	The personality CRC is incorrect	1
16	Line Contactor Welded Fault	Line contactor is welded.	4
17	Line Contactor did not Close Fault	Line contactor is open circuit.	4
18	No Fault		On
19	Motor Open Circuit	Motor Open Circuit detected.	4
20	MOSFET Short Circuit	Short circuit Armature MOSFETs detected.	3
21	VA Detect Fail	12V Supply Failure – not used	0
22	MOSFET Off	MOSFETs did not pulse during power on failsafe checks (failsafe circuit enabled).	0
23	MOSFET On	MOSFETs pulsed during power on failsafe checks (failsafe circuit disabled).	0
24	MOSFET Short Circuit during Power Up	Short circuit Armature MOSFETs detected during power on failsafe checks.	3
25	Drive 2 Off	Contactor 2 did not pulse during power on failsafe checks (failsafe circuit enabled).	0
26	Drive 2 On	Contactor 2 pulsed during power on failsafe checks (failsafe circuit disabled).	0
27	Drive 1 Off	Contactor 1 did not pulse during power on failsafe checks (failsafe circuit enabled).	0

28	Drive 1 On	Contactactor 1 pulsed during power on failsafe checks (failsafe circuit disabled).	0
29	Drive 3 On	Contactactor 3 pulsed during power on failsafe checks (failsafe circuit disabled).	0
30	Drive 3 Off	Contactactor 3 did not pulse during power on failsafe checks (failsafe circuit enabled).	0
31	High Capacitor Voltage	High capacitor voltage detected.	7

Table 11: Fault Numbers and Descriptions

Fault Clearance

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

Fault Reporting Form

Sevcon is committed to improving the quality of all of its products. Please help us by using this form to report faults to Sevcon. Please provide as much detail as possible. Use extra sheets if required. Fax this form to +44 191 482 4223.

Your Name		Telephone Number	
Your Company		email address	
Vehicle Manufacturer		Vehicle Type	
Controller Type		Part number	
Serial Number		Software Version	
Date / Time that fault first occurred.			
Exact Fault Message (calibrator or display)			
When did the fault message appear?	during drive / when the vehicle stopped / in neutral / after a key switch off-on (delete as applicable)		
How did the fault occur? Please describe: The vehicle speed. The approximate gradient (up or down hill) Pedal and switch changes by the driver What happened to the vehicle when the fault occurred			
What is the status of the vehicle now? Is there a fault message at key-switch on? Can it be driven?			

Table 12: Fault Reporting Form

Software Version and Serial Number indication

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

The Software version is shown as a string, scrolling continuously across the calibrator display from right to left. The format is:

Test Item:	S/W Version
Version Number:	8 characters

Table 13: Software Version Format

The Serial number is shown across three items in the Test menu. The first item is the date code and the next two are the identifier. All these items need to be used to get the complete serial number. The format is:

Test Item:	Ser No. Date	Ser No. ID1	Ser No. ID2
Serial Number:	MMYY	AA	BB

Table 14: Serial Number Format

MMYY gives the month and year when the controller was manufactured. (e.g. 0701 would indicate July, 2001). AABB are combined to give a 4 digit identifier which is simply a number from 0001 to 9999. When giving the Serial Number, the entire number should be quoted (i.e. MMYYAABB).

The MillipaK range of controllers uses the latest FLASH technology to allow In System Reprogramming. This can be achieved without the need to remove the controller from its installation; all that is needed is connection to the 6-way calibrator socket.

Specifications

The following specifications apply to all MillipaK controllers.

Power Configurations

At present the MillipaK SEM controller is available in the following power configurations:

Housing	Armature	Field	Soft Start Option
(HP) Large	500A	40A	NA

Table 15: Power Configurations

All the MillipaK SEM range of controllers operate from 24-48v batteries.

EMC standards

All MillipaK variants are tested to and conform to EN12895.

Socket B protection

All user connections on socket B are protected against indefinite short circuit to battery minus and battery positive.

Contactor drive ratings

All contactor drives are rated at 3A peak (10s) and 1.5A continuous. All the drives have reverse battery connection protection, inbuilt freewheel diode and are internally protected against short circuit.

Analogue Input Impedance

The two analogue inputs are internally pulled up to +12v via a 12k resistor. This is primarily designed for use with 5k potentiometers, but may also be used with suitable voltage sources.

Digital Input Impedance

The digital inputs are internally pulled up and are active LOW. They therefore must be connected to battery minus to operate a function. Maximum resistance to battery minus to operate is 500ohms.

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.

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 minimize 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.

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.

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 any changes, consider their effect on compliance ahead of any consideration of cost reduction or other "improvement".

Ordering Information

The controllers and contactor panels are allocated 633 numbers as shown. The lettering section gives the full listing of item types.

Item description	Voltage	Current	Logic	Customer Code
A=	2= 24	1= 100-199	1= SEM plug	XX
B=	3= 36	2= 200-299	2= SEM plug s/start	
C= Controller only	4= 48	3= 300-399	3= SEM regen	
D= Traction panel	7 = 72	4= 400-499	4= SEM regen s/start	
E= Traction + Pump Panel	8= 80	5= 500-599	5= Series Pump	
F= Twin Traction Panel	9= 96	6= 600-699	6= BPM	
G= Twin Traction + Pump Panel		7= 700-799	7= BPM s/start	
H=		8= 800-899	8= 4QPM	
J=		9= 900 +	9= 4QPM s/start	
K=				
L=				
M=				
N=				
P=				
R=				
S=				
T= HP Controller only				
W= HP Traction panel				
X= HP Traction + Pump Panel				
Y= HP Twin Traction Panel				
Z= HP Twin Traction + Pump Panel				

HP = High Power

For panels then the voltage, current and logic numbers should be used to describe the traction controller.

Examples:

300A SEM plugging controller with soft start 633C43101

600A SEM plugging controller 633T46101