TSE1000/TSE550/TSE600

DRIVE MOTOR CONTROLLER PRODUCT MANUAL

VERSION 2.1 (Change this Update Version)

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I. INTRODUCTION

A. ABOUT THIS MANUAL

This manual outlines the use of the **TSE1000**, **TSE550**, and **TSE600** motor controllers from Navitas Technologies. From time to time the manual will also refer to other NAVITAS products (the **ProBit**, the **PSE1000** and **PSE550** pump controlllers, and the display). In general we have tried to provide the information you will need to make these products work with the **TSE1000/TSE550/TSE600**, but for a more thorough explanation of these items you will need to consult their respective product manuals.

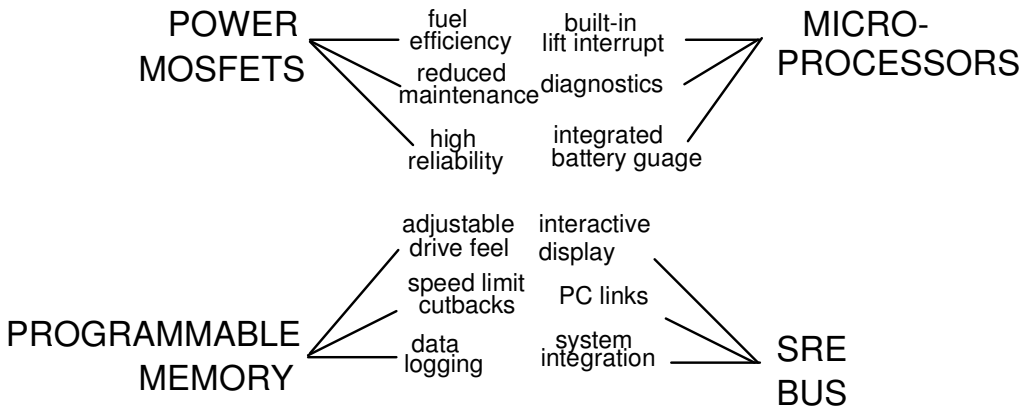
IF YOU ARE DOING A QUICK INSTALLATION go to chapter III and read sections A - D. These sections give you instructions for wiring your truck and controller, and programming the basic settings you will need. (Please note that first installations should not be done quickly because of the damage that may result from incorrect proceedures.)

IF YOU ARE NEW TO NAVITAS TECHNOLOGY, chapter I will give you a helpful overview of what NAVITAS control systems can do for your truck and your management of the truck. Chapter II. then goes through each circuit, switch and contactor, explaining how the controller works with each of these.

IF YOU ARE HAVING TROUBLE WITH AN INSTALLATION refer to chapter III, section F for help in identifying the problem. For additional information you can turn to the appropriate section of chapter II for more detailed explanation of how a particular feature works.

IF THE TRUCK NEEDS SERVICE, chapter II, section V will give you information on error codes which can help to pinpoint the problem, and chapter IV gives instructions for servicing your truck.

B. THE FUNDAMENTALS OF NAVITAS TECHNOLOGY[1]



POWER MOSFETs

MOSFETs (Metal Oxide Semiconductor Field Effect Transistors) give our controllers the ability to handle high power without consuming as much energy as SCR systems. Controllers that use SCRs consume a lot of energy turning the SCR switch on and off and require an extra circuit to do so. In contrast, MOSFETs switch on and off without any extra circuitry or wasted energy. They also switch much faster (20,000 times per second rather than 200 times for SCRs). The results are more efficient use of energy and smoother, quieter operation.

MICROPROCESSORS

Microprocessors give NAVITAS products their intelligence. We use microprocessors to collect information from one part of the truck and apply it to another. For example, microprocessors calculate battery charge, perform diagnostics, regulate the motor speed according to the lift mast height, and keep the system operating within thermal limits and current limits. In short, we use microprocessors in our controllers to give the vehicle the capabilities of a computer.

PROGRAMMABLE MEMORY

The programmable memory designed into every NAVITAS controller gives the operator a new level of control over the vehicle's performance. More than 20 vehicle functions which are stored in the controller's memory can be changed by the operator using the ProBit. Top speed, lift-and speed interlocks and even the time it takes to pull contactors in can all be set and reset in the controllers' programmable memory.

THE NAVITAS BUS

All NAVITAS products can communicate together through a link called a "BUS". Because of this communication link our products act as a system rather than individual parts working alone. For example, when a pump controller is added to the motor controller, they cooperate to determine battery levels and send that message to the display and the ProBit. The BUS also enables you to install additional NAVITAS products over time.

C. TSE1000/TSE550/TSE600 MOTOR CONTROLLERS

The TSE1000 and TSE550 are drive motor controllers for electric lift trucks. The **TSE1000** is designed for trucks with 24 - 48 volt batteries and weight classes of up to 10,000 lbs. (although it has been used in 12,000 lb. applications). The **TSE550** is

[1]U.S. patents are pending on NAVITAS motor controller technology.

designed for 24 - 48 volt, 2,000 - 5,000 lb. systems. The **TSE600** is designed for 60 – 96 volt, 2,000 – 5,000 lb. systems. The **ProBit** lets you read the information stored in the controllers and it also allows you to change the settings that are programmed into them. Service personnel can adjust operation to suit the truck and the operator.

The technology and innovation of the TSE1000/TSE550 offers four major advantages when compared with other control systems:

1) reduced maintenance and repair
2) improved performance
3) fleet management features
4) driver safety and vehicle protection.

1. Reduced Maintenance and Repair.

Several features of the TSE1000/TSE550/TSE600 reduce wear and tear on contactors, motors and batteries and also increase the reliability of the controllers themselves. These savings alone support the change to NAVITAS technology since the cost of one motor rebuild can more than pay for an NAVITAS retrofit.

FEATURE	ADVANTAGE	BENEFIT
Cold Contactor Switching	Whenever the direction contactors are pulled in or out the motor voltage is set momentarily to 0. This reduction in current eliminates arcing.	Reduces contactor tip wear.
Low Contactor Hold-Voltage	The voltage required to hold a contactor in is lower than the voltage needed to pull it in. The TSE1000, TSE550, and TSE600 allow you to set a low contactor hold voltage so that less heat is passed through the coils.	Increases life of contactor coils and lowers fuel consumption.
Peak Motor Current Limit	This limit protects the motor against very high surges of current.	Protects the brushes and commutator.
Average Motor Current Limit	This limit allows temporary peaks of current, but prevents long-term currents which are higher than recommended motor ratings.	Reduces burn-outs and lengthens life of motor windings.
Diagnostics	The controller keeps watch over several functions of the vehicle and keeps a record of problems as they arise. This record is a valuable maintenance tool.	Reduces time to repair.

Table 1: Reduced Maintenance and Repair

2. Improved Performance

The TSE1000/TSE550/TSE600 use highly efficient MOSFETs instead of SCRs. SCR controls create a lot of heat while they operate. This heat shortens the life of those controllers and can set the truck into thermal cutback. In contrast, the TSE1000/TSE550/TSE600 performs at lower temperatures and does not waste energy through heat dissipation.

The TSE1000/TSE550/TSE600 also offers more than twenty programmable performance settings. You can use your controller with the factory preset levels or you can program the controller to suit the strengths and weaknesses of your particular vehicle.

3. Fleet Management

A unique feature of NAVITAS technology is the ability to collect information about vehicle use. The TSE1000/TSE550 clocks on-times, drive-times, and lift-times making fleet management statistics readily available. Managers can more easily collect accurate information on average time to repair, justify the purchase of new vehicles, or determine how to make better use of the current fleet. In addition, each TSE1000/TSE550/TSE600 can store the settings for several operators so that the same truck can be used safely and efficiently in more than one shift.

4. Driver Safety and Vehicle Protection

The TSE1000/TSE550 includes standard features which increase the safety of operation and protect the vehicle from misuse. These features include several interlocks and a number of current limits:

The **safe sequencing interlock** ensures that the driver is in safe control of the vehicle at all times. The TSE1000/TSE550/TSE600 links together the dead-man switch, the accelerator and the direction switches so that the truck will not jerk or move by accident.

The **battery discharge interlock** ensures that the truck will not continue to draw current from a battery that needs to be recharged. It ties the lift controls to the battery level so that drivers cannot continue to operate the lift after the battery has consumed all of its usable charge.

The TSE1000/TSE550/TSE600 **service brake interlock** shuts off all vehicle controls while the service brake is activated. In this way, the controller adds an extra level of safety to these mechanisms.

The **speed limit cutbacks** can be connected to mast switches. In this way the TSE1000/TSE550/TSE600 will limit the speed of the vehicle as the lift mast is raised.

Current limits include the **battery current limit**, the **peak motor current limit**, and the **average current limit.** The battery current limit regulates the amount of current the system can draw from the battery. The peak motor limit controls the absolute maximum current to the motor. The average current limit controls the continuous current to the motor so that the average duty will not be excessive.

5. Exterior Dimensions

The following diagram gives the case dimensions of the TSE1000/TSE550/TSE600.

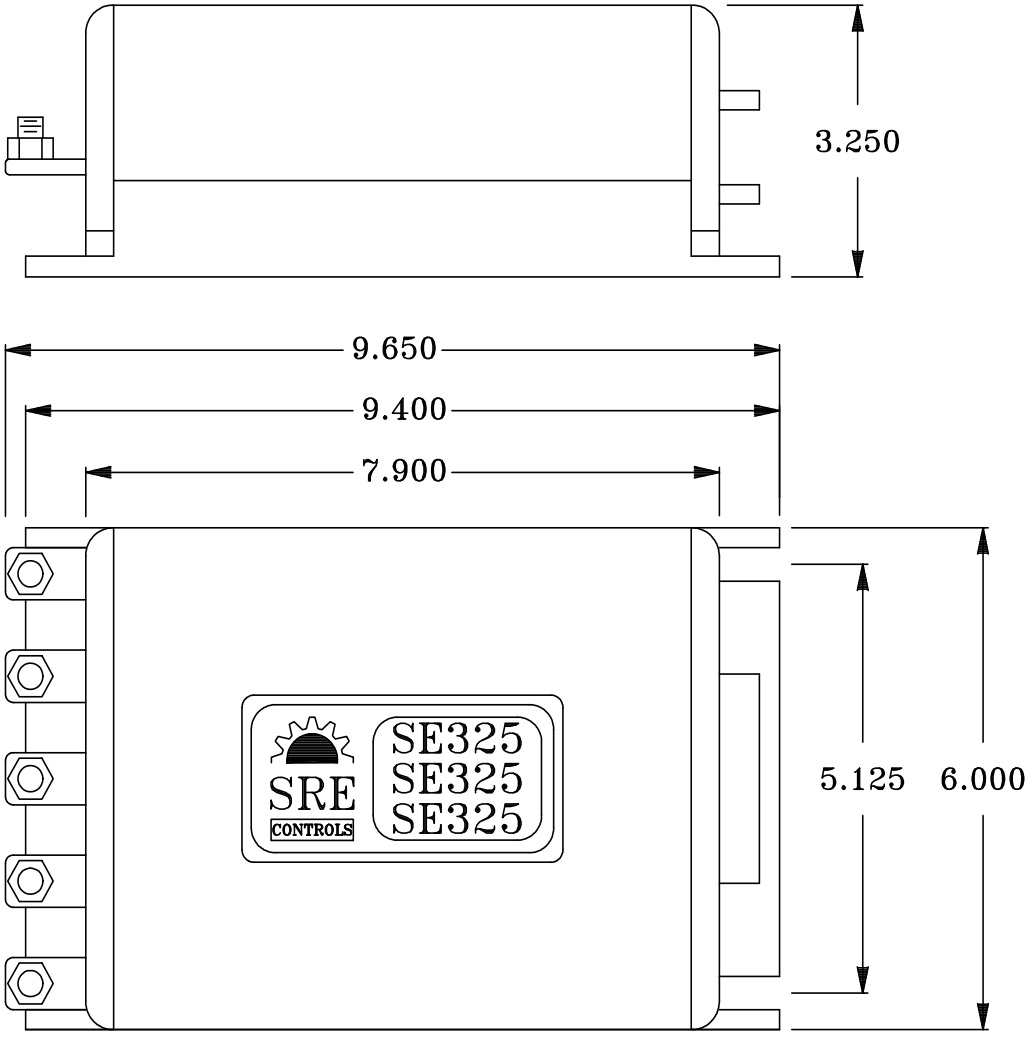


Figure 1: Mechanical Layout

6. Power Wiring Schematic

The following diagram represents the flow of power through an electric vehicle using an TSE1000/TSE550.

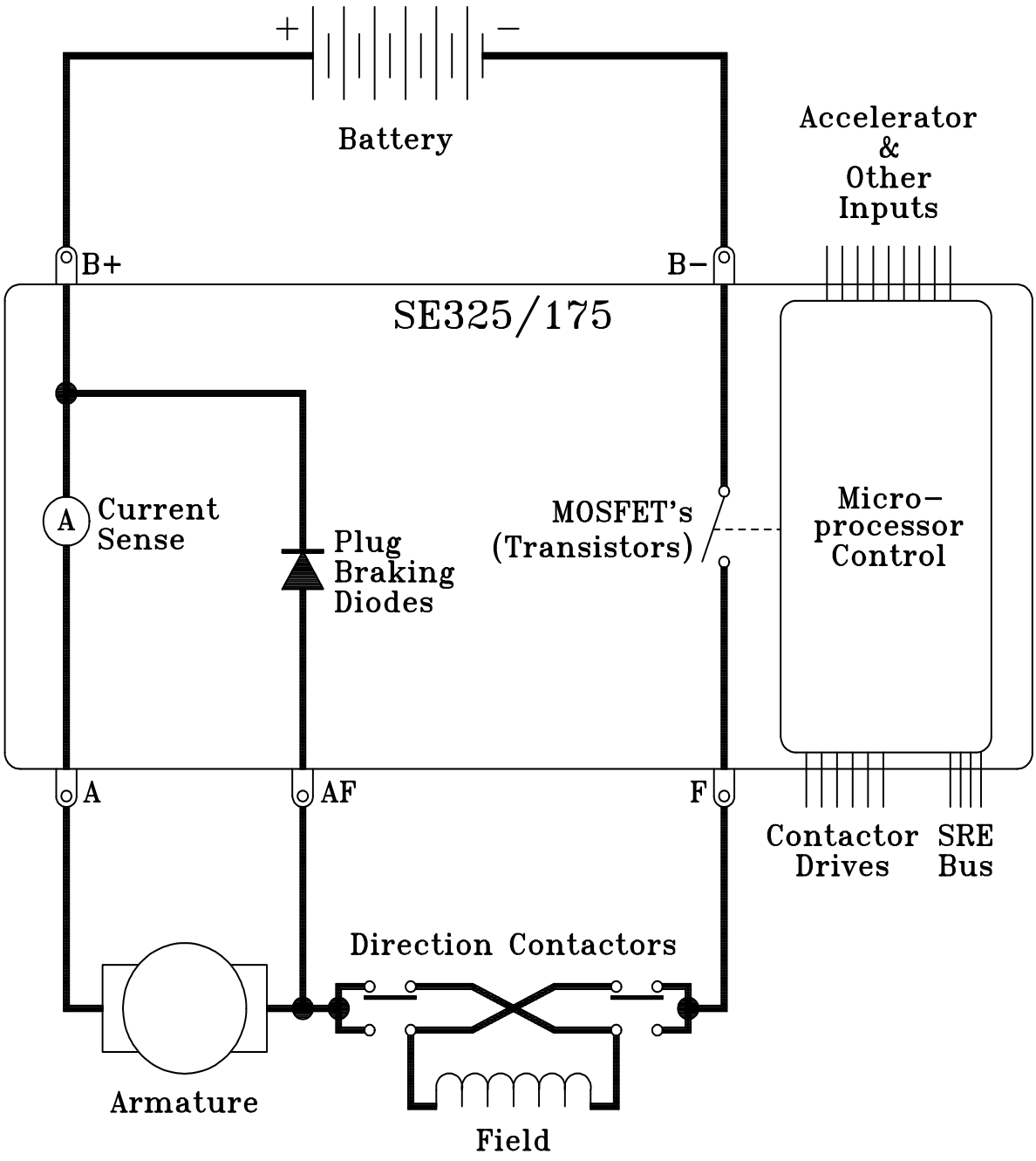
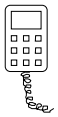


Figure 2: General Power Wiring Layout

II. HOW IT WORKS

The following section describes in detail how the controller works. This section covers all of the vehicle's switches, contactors and other controls, as well as current limits, interlocks and other functions of the controller. If a particular feature is programmable, you will find the programming icon (the picture of the ProBit shown below) beside the programming instructions.

The step-by-step instructions for wiring are found in Chapter II, *Installation Procedures*; beginning on page 20.



A. KEY SWITCH

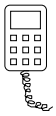
The key switch provides battery voltage to the controller, and, therefore, the controller will not work until this switch is connected. The controller requires a 10-20 Amp fuse at this switch.

B. PLUG BRAKING

Plug braking lets the driver change directions without stopping the truck first. The controller slows the vehicle down to a stop and speeds it up again in the opposite direction whenever the accelerator is pressed while the direction is changed.

A motor changes direction when the polarity of the motor field is reversed. If the field is reversed while the armature is spinning the armature acts like a generator. The energy generated in this way is directed through the plug braking diodes in the controller and dissipated through them and the armature. The controller regulates the flow of current through the armature so that the truck will come to a stop and change directions smoothly.

The farther you push the accelerator, the stronger the plug braking will be.



The feel and strength of plug braking can be changed with the **ProBit**. Two main settings affect the operation of plug braking: 1) plug braking strength (motor current); 2) deceleration (the amount of time to get to maximum plugging strength). You should adjust these levels one at a time since they affect one another.

1)The ProBit allows you to set the strength of plug braking by changing the amount of armature current. (The amperage you set is the current you will get with the pedal to the floor.) The higher the amperage, the stronger the plugging.

2)Deceleration is set in seconds. A setting of 0.4 seconds means that it will take 0.4 seconds from the time the driver changes direction until the motor to reaches full plugging current.

Two other parameters may have some effect on the operation and feel of plug braking: i) direction change time and; ii) contactor change time.

i) The time you can leave the direction selector in neutral when moving from forward to reverse is known as a "forgive time". If the switches are in neutral for longer than this forgive time the controller sets off an RTN, or Return to Neutral, (see *Safe Sequencing*; p. 8). The driver must then go through the start-up sequence again. Since drivers have different habits when changing directions you can set this time to allow for their speed of shifting directions. See the **ProBit** manual for more information on setting parameters.

ii) The time allowed for a direction contactor to pull in will change the way plug braking feels. If you set this time high, the plugging may appear to lag for a moment while the controller waits for the contactor to pull in. If you set the time too low, the truck will fail diagnostics. A good contactor should be able to change in 0.15 seconds, but older contactors may be slower.

C. SAFE SEQUENCING

Safe sequencing is a safety feature which ensures the accelerator cannot be activated accidentally. The "safe sequence" is the order in which the driver must operate the vehicle controls. The correct operating sequence is:

1) Get into safe operating position (seated on the seat in a rider or standing on the floor panel in a stand-up). This is the position that closes the SRO switch (see *"Dead-Man" Switch (SRO Switch)*; below).
2) Select a direction.
3) Press the accelerator.

Each time drivers start the truck from a stop they must take their place and return the direction selector to neutral before selecting a direction and accelerating. If a driver operates the controls out of order, the controller returns the truck to neutral. The controller also causes a Return To Neutral, or RTN, for other safety reasons, including SRO (see *"Dead-Man" Switch (SRO Switch)*; below) and battery current limit (see *Battery Current Limit*; p. 15).

D. "DEAD-MAN" SWITCH (SRO SWITCH)

The "dead-man" switch (the brake switch in walkies) returns the truck to neutral (RTN) if a driver falls off. After RTN, the truck will coast to a stop. This switch is connected to the seat in rider trucks and to the floor panel in stand-ups.

When the driver is in correct driving position, the dead-man switch is closed and the controller reads a voltage. Whenever the driver gets off the seat or floor panel (or lets go of the operating arm in a walkie) the switch opens and the voltage reading stops. To start the truck again, drivers must carry out the safe sequencing steps.

E. ACCELERATOR SWITCH AND SERVICE BRAKE SWITCH

The accelerator switch and the service brake switch do not appear in every model of lift truck. When these switches are used they provide an additional level of safety. (The accelerator switch is an additional check on the accelerator and the brake switch prevents the controller from trying to drive the truck with the brake on.) The controller can be wired to use one, both, or neither of these switches. When both are used they ensure that the truck will not move unless the brake is off and the accelerator is on.

If your truck does have an accelerator switch it must be a normally open switch (that is, closed when the accelerator is pressed and open when the accelerator is at its "rest" position). The brake switch must be a normally closed switch (that is open when the brake is on and closed when it is not). When the controller reads no voltage from these switches (that is when the switches are open), the direction contactors will operate, but the controller will not supply voltage to the motor.

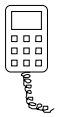
F. ACCELERATOR

The accelerator controls the speed of the truck by controlling the motor voltage. By pressing on the accelerator pedal the driver changes the drive motor voltage. As explained earlier (see *Safe Sequencing*, p. 8), the TSE1000/TSE550/TSE600 will cause an RTN if the accelerator is pressed out of sequence.

As shipped the TSE1000 and TSE550 require a standard 5000 ohm, ½ watt (or larger) potentiometer with a reading of 5000 Ohms at rest and 0 Ohms at full speed. A minimum 2 Watt potentiometer is recommended for mechanical stability. The controller uses three settings--called throttle maximum, throttle minimum, and throttle polarity--to regulate the accelerator.

The TSE1000 and TSE550 are set up for 5K - 0 ohm linear potentiometers (where 5K is rest and 0 is full speed), but other potentiometers can be used as well. If you are using a non-linear pot make sure that the resistance at half accelerator is greater than 2500 Ohms. If it is less than this level the truck will be jumpy.

1. Throttle minimum and Throttle maximum

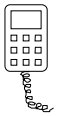


The throttle minimum and maximum can be set with the **ProBit**. The values are measured as a percentage of full accelerator.

The throttle minimum must be set correctly. It should be set just above the actual level the potentiometer reaches when it is at rest (often this reading will be less than 5000 Ohms). If this setting is wrong the controller may not operate because the accelerator will seem to be "activated" all the time and the safe sequencing interlock will be set off.

The throttle maximum is critical to attaining the maximum speed (full battery voltage on the motor) of the truck. If it is set too low you will never get the full motor voltage (or speed) possible for the vehicle. If it is set too high then the bypass contactor (if it is used) will be pulled in too soon(see *Bypass (1-a) Contactor*; p. 12). When this level is set properly, the controller will operate most efficiently (at a lower temperature, and, therefore, with less chance of a thermal cutback and a longer controller life).

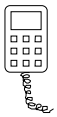
2. Drive Feel



The drive feel of the truck can be adjusted by changing the top speed (motor voltage) and the acceleration. These settings are adjustable in the performance section of the **ProBit**. The maximum motor voltage (speed) is measured as a percentage of battery voltage and may be adjusted independently for forward and reverse. Acceleration is measured by the amount of time it takes to travel from zero to full motor voltage. Acceleration may also be set differently for forward and reverse.

The maximum speed (applied motor voltage) and acceleration settings are used as reference points for the speed limit switches (See *L. Speed Limit Switches*; p. 13).

3. Throttle Polarity



The controller can be programmed to reverse the polarity of the accelerator/throttle, so that 5000 Ohms is full speed and 0 Ohms is rest. You will need to set the throttle minimum and maximum after you change throttle polarity.

NOTE: The potentiometer always defaults to 5000 Ohms when there is a faulty connection. Therefore, if a wire comes loose when the polarity is reversed the truck will go to full speed.

4. Accelerator Configurations

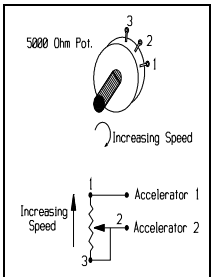


Figure 3: Unidirectional 5K Potentiometer

As shipped the TSE1000/TSE550/TSE600 requires a two terminal, resistive potentiometer of 5000 Ohms, but it can be installed to work with other pots as well. The four standard potentiometer types for lift trucks are: 1) a 5000 Ohm, three terminal potentiometer with separate direction switches, 2) a 20000 Ohm, three terminal potentiometer with integrated direction switches, 3) a 5000 Ohm, three terminal potentiometer with integrated direction switches, and 4) a four terminal, center tapped, 10000 Ohm potentiometer.

a) 5000 Ohm Pot./Separate Direction Switches

Figure 5 shows the arrangement for a resistive, pedal accelerator. The accelerator controls the speed, and direction is controlled by a separate switch (or set of switches).

The controller wire called *accelerator 1* should be tied to one end of the pot and the wire for *accelerator 2* should be tied to the wiper (as shown in figure 3, p. 10). The connection from the wiper to the other end of the potentiometer is optional. The two ends of the accelerator should be wired so that the accelerator travels from 5000 Ohms to 0 Ohms as it is pressed.

b) 20000 Ohm Pot./Integrated Direction Switches

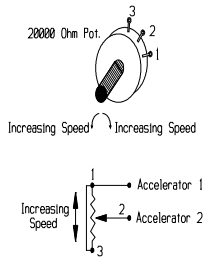


Figure 4: Bi-directional 20K Potentiometer

This arrangement is sometimes used in twist grip or lever accelerators where a single accelerator controls both the speed and direction. The switches for the direction selection are generally activated by an internal cam. The two ends of the potentiometer are wired together to the controller input *accelerator 1* (see Figure 4, p. 10). The wiper is wired to the input *accelerator 2*. When the wiper is in the center of the potentiometer this circuit will have an effective resistance of 5000 Ohms, when the wiper is at either end the effective resistance will be 0 Ohms.

You must be sure that the wiper is at the center of the potentiometer when the direction switches are in neutral. If it is offset in either direction by a significant amount the truck will not travel in that direction because the accelerator will seem to be activated and the truck will fail the safe sequencing check.

c) 5000 Ohm Pot./Integrated Direction Switches

Other twist grip and lever accelerators use this arrangement. The 5000 Ohm potentiometer is wired as explained in "a) 5000 Ohm Pot./Separate Direction Switches", p. 10. In this case the cam assembly in the accelerator not only switches the direction but also turns the potentiometer in the same direction either side of neutral.

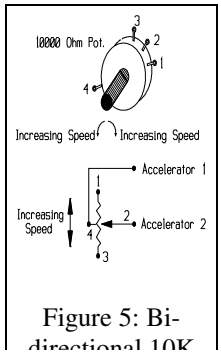


Figure 5: Bi-directional 10K

d) 10000 Ohm 4 Terminal Pot./Integrated Direction Switches

The final arrangement for twist grip and accelerator levers appears in Figure 5 The center tap (terminal 4; see figure 5) is wired to the controller input *throttle 1* and the wiper is wired to the input *throttle 2*. The two potentiometer endpoints are left open. In this configuration the accelerator/throttle value will travel from 0 Ohms at rest to 5000 Ohms at full speed. Using the ProBit, you must reverse the throttle polarity for this pot since it works backwards from the usual configuration.

WARNING: If you have a faulty circuit when you are using this configuration, the truck will go to full on.

5. Other Accelerators

a) Sevcontrol

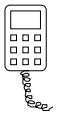
The Sevcontrol, manufactured by Sevcon can be used with the TSE1000/TSE550/TSE600. You should begin by opening the cable and finding the red, white, green and black wires.

Connect the red wire to the key switch. Connect the black wire to the accelerator 2 input pin on the TSE1000/TSE550/TSE600. Connect the green wire to the accelerator 1 pin on the TSE1000/TSE550/TSE600. You can connect the white wire to the accelerator/brake input pin on the controller or you can leave it unconnected.

G. DIRECTION CONTACTORS

The TSE1000/TSE550/TSE600 controller requires direction contactors. The forward and reverse direction contactors reverse the polarity of the motor field, and in that way they change the direction of motor rotation.

The controller runs regular checks on the contactors whenever you start the truck and whenever you change directions. It checks to make sure the contactors are pulling properly, have not welded, etc. Because of these checks you will experience a slight delay whenever you start your truck and whenever you change directions (see Startup Diagnostics, p. 17).



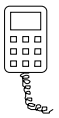
You can adjust this delay by lengthening or shortening the contactor change time with the **ProBit**. If the time is too long, the truck will appear to be "sluggish" when changing directions. If it is too short, the truck will fail diagnostics because the contactors will not be able to change in the time you have set. If you find that the pull-in time is too long and it cannot be reduced without failing contactor diagnostics then you should consider replacing the contactors with a faster set.

The factory setting for contactor change time is ½ second which should work with even the slowest contactors. In most cases, you will want to shorten this time. If you have a good set of contactors you should be able to reduce the time to 0.15 seconds.

The controller will not pull in a direction contactor: 1) when certain errors are detected, and 2) if the controls are not operated in the safe sequence (i.e., the accelerator is activated before the direction is selected, etc.).

H. STEERING PUMP

The steering pump contactor pulls in when a direction is correctly selected. It drops out again some time after returning to neutral or some time after the dead-man switch is opened.



These times are fully programmable in the miscellaneous timings section of the **ProBit** and are generally set to between 5 and 30 seconds. See the ProBit manual for more detailed information.

I. LIFT PUMP

Power to the lift mechanisms is regulated by the lift pump contactor, or by the NAVITAS **PSE1000/PSE550** pump controller. If you are using the PSE1000/PSE550 please see its manual for more details.

Normally, the lift pump contactor can be pulled in whenever the key switch is on. However, when the battery is low the controller pulls the contactor out so that the driver must have the battery recharged before continuing. (See *Battery Discharge Interlock*; p. 14 for more information.)

For added safety, the lift pump contactor can be programmed to turn on only when the safe sequence is followed. This measure ensures that the hydraulics will work only when the driver is in the proper driving position. You can set this interlock in the miscellaneous timings section of the **ProBit**.

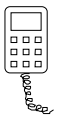
J. BYPASS (1-A) CONTACTOR

The bypass contactor, sometimes called the 1-A contactor, was used in older controllers to "bypass" the controller and supply full battery voltage directly to the motor.

Previous generations of controllers use inefficient power devices. These controllers have a large voltage drop and overheat quickly under heavy loading. Because of this drain of power some of the voltage that might go to the motor is consumed by the controller. To lessen these problems, a "bypass" feature was introduced in some models. Bypass is essentially a switch in parallel with the controller. When the bypass contactor is closed, the flow of current "bypasses" the controller and all its inefficiencies. In this way bypass allows full battery voltage to go to the motor and allows the controller to cool down.

Bypass can be dangerous because it removes the regulation of the controller while the bypass contactor is pulled in. Under these conditions, the motor and the battery can be abused and if the contactor welds the truck will "run away".

NAVITAS controllers do not need to be bypassed. The TSE1000 and TSE550 use technology that is much more efficient than the older technology. They consume significantly less energy and they perform at lower temperatures. For these reasons, the regulation of the controller never has to be removed for the sake of efficiency. However, if you want to you can continue using the bypass feature with the TSE1000/TSE550/TSE600. If your truck has been using bypass we recommend that you take a trial period without it and compare the performance. (See *Bypass*; p. 21 for installation.)



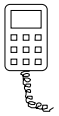
You can program the bypass option using three parameters in the Bypass/Field Weakening section of the **ProBit:** 1) The bypass enable lets you turn the bypass on or off. If you turn the bypass on, you must be sure to connect the bypass contactor. 2) The bypass level is measured as a percentage of battery voltage (usually set at 95%). When the output of the controller reaches this level (and stays there for a preset time) it pulls in the bypass contactor. When the controller output is ready to drop below this level again the controller drops out the contactor. 3) The bypass delay is measured by the length of time the controller must hold the bypass level before the contactor pulls in (usually about 5 seconds).

To avoid the severe arcing that can occur in these conditions, the controller output goes to 100% during the time the contactor is switched.

K. FIELD WEAKENING

Some trucks are equipped with a field weakening resistor to gain higher speeds with reduced torque. The controller switches the resistor in and out using the field weakening contactor. In cases where a truck has multiple field windings, the controller uses field weakening to short out one of the field windings and so decrease the number of turns in the field.

The controller reads two levels to determine when to pull the contactor in and out: 1) motor voltage and 2) motor current. When a driver is operating on a flat surface with a light load, the accelerator (and the motor voltage) will typically be at full, and the motor current will be low. When a truck is carrying a heavy load up a grade, the current will be high. When the controller detects the first set of conditions (i.e. full motor voltage and low motor current) the controller pulls in the field weakening contactor. When the driving conditions change or the motor voltage drops to a preset level the controller pulls the contactor out again.



You can program field weakening with three parameters in the bypass/field weakening section of the **ProBit**. The first parameter, the *Bypass level,* is shared with the bypass contactor. This level sets the motor voltage above which the field weakening contactor can be pulled in. As long as the motor voltage is below this level neither the bypass nor the field weakening contactor can be pulled in. The second parameter is called the *pull-in level*. Field weakening is activated when the motor voltage is above *Bypass level* but the motor current is lower than the *pull-in level*. The *pull-out level* is the motor current above which the field weakening contactor will pull out.

The following table shows how these three levels work together.

	VOLTAGE HIGHER THAN BYPASS LEVEL	VOLTAGE LOWER THAN BYPASS LEVEL
MOTOR CURRENT LOWER THAN PULL-IN LEVEL	Field weakening contactor pulls in.	Field weakening contactor drops out.
MOTOR CURRENT HIGHER THAN PULL-IN LEVEL AND MOTOR CURRENT LOWER THAN PULL-OUT LEVEL	Field weakening contactor stays as it was.	Field weakening contactor drops out.
MOTOR CURRENT HIGHER THAN PULL-OUT LEVEL	Field weakening contactor drops out.	Field weakening contactor drops out.

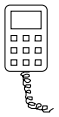
Table 2: Field Weakening Functioning

NOTE: The pull-in level MUST be less than the pull-out level.

L. SPEED LIMIT SWITCHES

Speed Limit Switches (also called "Cutback Switches") allow you to limit the motor voltage (which controls speed) when the truck is operating under specified conditions. For example, you can program the truck so that the top speed cuts back whenever the mast is fully raised. There are three speed limit switches which can be interlocked for three different conditions and three different top speeds.

As shipped, the speed limits are set to 80%, 60%, and, 40% of maximum speed and acceleration (braking remains at 100%). For example, when a mast micro-switch indicates that the lift is up, the truck speed can be limited to 80%.



The performance levels for each of the speed limit switches can be set in the **ProBit**'s performance section. Each limit can be set as from 0% - 200% of top motor output (speed). This range allows each switch to be used as either a cutback switch or an overdrive switch.

NOTE: When speed is limited to less than 95% the bypass and field weakening contactors will not pull in.

M. NAVITAS BUS

This set of inputs is the backbone of the NAVITAS system. It allows multiple NAVITAS products (displays, ProBit, multiple controllers, pump controllers, drive controllers) to be connected together so that they operate in concert.

For example, if both a drive motor controller and a pump controller are used, the drive motor uses information from the pump motor to improve the accuracy of the battery gauge. The drive controller tells the display what the battery status is, and tells the pump controller to turn off when the battery is discharged.

Cables and wiring harnesses are supplied as needed. Due to the nature of electronic communication you must use only the NAVITAS harnesses. The pins for the bus (see the*Connector Pins* diagram on page 25) should be treated with care, because their inputs are not protected.

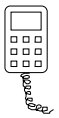
N. BATTERY MONITOR

The motor controller has a built-in battery monitor which judges the battery state by keeping track of battery voltage and motor current. When power is turned on, the monitor makes a first estimate of the battery level and improves this estimate as time goes on. It responds slowly to changing conditions. This estimate of the battery level can be shown on the display, or the **ProBit.** The battery gauge is most accurate at low capacities (below 50%) and after the truck has been operating for 5- 10 minutes.

O. BATTERY DISCHARGE INTERLOCK

The battery discharge interlock protects against over discharging the battery.

When the battery discharges to 0% usable charge (20% of total capacity), the truck is given a 5 minute "grace period" to finish an urgent task. When an NAVITAS dashboard display is used, the driver is notified at the start of the 5 minute grace period. After this period the lift contactor drops out and the truck goes into a "limp mode" to allow the driver to return to the charging area, but not to do any productive work. If the key is turned off and on again, the 5 minute grace period is reactivated.



The limp speed is measured as a percentage of motor voltage. It can be programmed with the **ProBit**.

The Battery Discharge Interlock can be disabled with the ProBit if you prefer to use external protection.

P. INTERLOCKS

1. "Static Return to Off" (see also Deadman switch p. 8)

For added safety, the controller will not operate (the direction contactors will not pull in) unless the correct sequence is observed.

The SRO is "satisfied" if the SRO input is connected to B+ **before** the direction selector is engaged **and before** the accelerator is activated. The SRO must remain connected to B+ and the direction must remain selected for the SRO to remain "satisfied".

SRO "forgive times" allow the SRO input to be temporarily disconnected from B+ (for example, the driver bounces from the seat momentarily) and the direction input selector to be temporarily in neutral (for example changing directions for plug braking). This time is set at ¼ second.

Under some conditions the controller forces an "RTN" (Return to Neutral). This happens, for example, when the battery current limit is momentarily exceeded, or the controller finds a contactor error. When an RTN occurs, the SRO must be satisfied again (see *Safe Sequencing*, p. 8).

2. Brake/Accelerator Switch

This input must be connected to B+. When it is not connected to B+, the motor output is 0, although the contactors will operate.

3. Battery Discharge

The Battery Discharge interlock prevents batteries from discharging too deeply. (See *Battery Discharge Interlock*; p. 14.)

Q. LOW VOLTAGE CUTOUT

If under any circumstances the battery voltage falls below 18 volts, the controller will shut down. It will not operate any contactors or provide any output, and other network devices may not be active.

R. TEMPERATURE LIMITS

If the controller temperature exceeds 85ºC, the controller limits the motor current in an attempt to lower the temperature. If the temperature continues to rise, the controller shuts down completely at 95ºC and will operate normally again after it cools down.

S. CURRENT LIMITS

1. Overview

The current limits in the TSE1000 and TSE550 protect the motor, battery, and the controller. The controllers include three current limits:

1) Battery Current Limit: a fixed limit on the current the controller can draw from the battery. This current limit responds very quickly.

2) Peak Motor Current Limit: a short term, fast current limit that controls the absolute maximum current that the controller can supply to the motor.

4) Average Motor Current Limit: a long term limit on the current that the controller can supply to the motor. This limit protects the motor from the overheating of long term peak currents.

2. Battery Current Limit

If the battery current exceeds its limit (650 Amps for the TSE1000, 400 Amps for the TSE550), the controller immediately sets the output to zero and returns the truck to neutral (see *Safe Sequencing*; p. 8). The controller will operate normally again after the SRO is satisfied and error code 5 will show on the ProBit.

The battery current limit protects against short circuits and shorted windings.

The battery current limit can be exceeded during excessive loading. For example, a battery in good condition, going up a 15% grade under full load at full accelerator may exceed the limit. This ramp may be climbed successfully at a lower speed.

3. Motor Current Limit

Electric DC motors typically have two different current ratings.

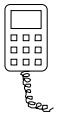
1) An absolute maximum peak current. Any draw above this level will damage the motor (via arcing at the brushes etc.).

2) A design current rating. If this limit is exceeded for long periods of time or on a frequent basis the motor will deteriorate through overheating.

You can set separate levels for these two limits in the current limits section of the **ProBit.**

a) Peak Limit

The peak limit protects the motor brushes and commutator from the effects of short term current demands. High torque conditions (such as stalling) draw currents that can exceed this limit. If the limit is exceeded the controller decreases motor output until the current is lower than the limit.



Using the **ProBit** you should set this level to the absolute maximum current that the motor can withstand. Manufacturer's specifications for the motor will list this level for each motor.

b) Average Limit

Although electric motors can handle large current draws for a short period of time, the continuous duty current that they can withstand is generally much lower. Continuing currents larger than the continuous rating of the motor will burn out the motor windings.

The TSE1000/TSE550/TSE600 lets you set the average limit separately from the peak limit. If the average current to the motor exceeds this limit the controller decreases the motor current to a safer level. In this way the controller allows large peak currents (and thus peak torque's) while still protecting against the damage caused by prolonged lugging or truck misuse (such as attempting to pull more than the truck was designed for).

4. Controller Limits

The final current limit protects the controller against excessively high current levels. This limit varies with battery voltage, temperature and other factors. The levels described here show the worst case you might experience.

The limits for the TSE1000 are illustrated here in *Figure 6* and those for the TSE550 are shown in *Figure 7* below. During periods of peak current the controller uses a protective control algorithm to provide the highest possible currents without damaging the system. As the temperature of the controller increases the controller will begin to use this algorithm sooner (i.e. at lower currents) and will lower the maximum allowable peak current. At temperatures above 85ºC the current limit is reduced significantly. The controller is shut down at 95ºC.

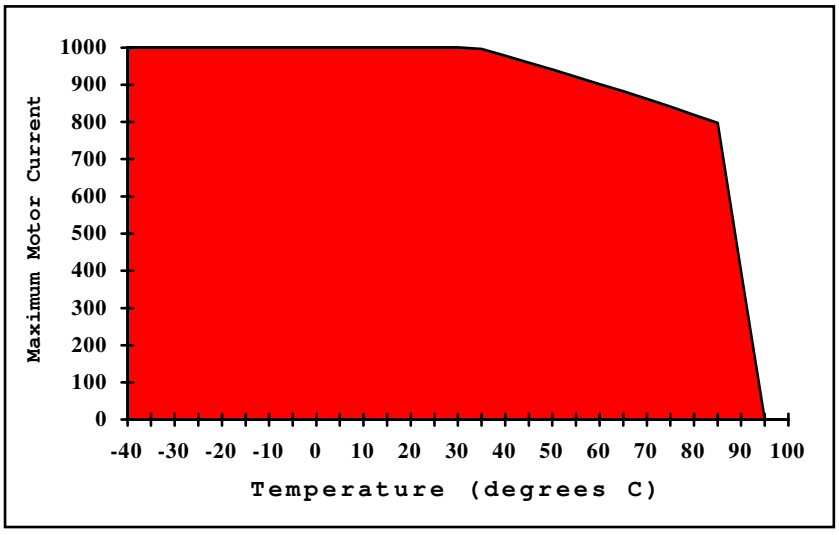


Figure 6: Maximum allowable motor current for TSE1000.

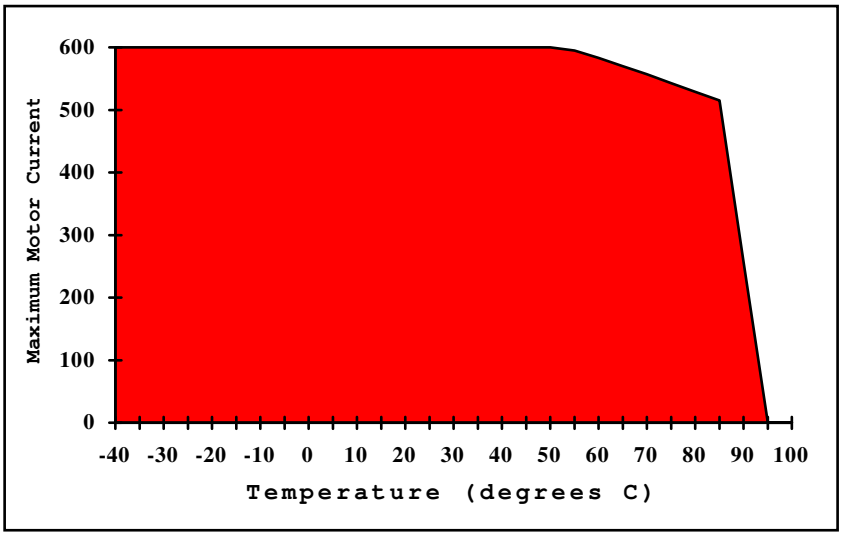


Figure 7: Maximum allowable motor current for TSE550.

T. STARTUP DIAGNOSTICS

The controller runs a series of self-diagnostic checks to ensure that it is working properly and that the truck is safe to operate. The controller tests itself for internal shorts, and then tests the system wiring and the contactors. If any of the diagnostic tests fail the controller logs the information and returns the truck to neutral.

At start-up the TSE1000/TSE550/TSE600 pulls in each of the direction contactors to check the path from the armature through the field. These tests will fail if the motor is not wired correctly, if the contactors do not pull in quickly enough, or if the contactor coils are shorted.

Trucks may fail to pass this test after installation because of wiring errors.

U. RUNTIME DIAGNOSTICS

While the truck is running the TSE1000/TSE550/TSE600 continues to run checks for failures during operation. These tests include checks for welded or failed contactors (see *Direction contactors*; p. 11). If a failure is detected the controller will log an error code which identifies the problem. You can use the **ProBit** to read the record of errors.

V. ERRORS AND DATA LOGGING

The TSE1000/TSE550/TSE600 controller keeps a record of errors and certain operating conditions. This record may be read at any time using the ProBit. It provides useful information for service and fleet management.

1. Error Codes

If the controller diagnostics find an error it is recorded for later reference. A partial list of error codes is outlined in the tables below. See the ProBit Manual for a complete list.

If the controller fails any of these tests it will disable the truck. Each time the key is turned off and on the diagnostics will run again and continue to fail until the problem is solved.

No.	ERROR (start-up)	DESCRIPTION
20	Sticky direction contactor	Either a direction contactor is welded, or there is a short between F and AF.
21	Bypass contactor error	Either the bypass contactor is welded or there is a short between F and AF.
23	Forward contactor failure	The forward contactor will not pull in and no short has been found.
24	Reverse contactor failure	The reverse contactor will not pull in and no short has been found.

Table 3: Errors Recorded During Start-Up Diagnostics

No.	ERROR (run-time)	DESCRIPTION
3	Parameter fault	The controller found and corrected an error in the parameters.
5	Battery current limit	The current limit for the battery has been exceeded.
10	Direction switch conflict	Both direction switches were selected at the same time.
13	Shorted lift contactor	The lift contactor is shorted or drawing too much current.
14	Other shorted contactor	One of the vehicle's other contactors is shorted.
33	Welded direction contactor	One of the direction contactors is welded.
35	Welded bypass contactor	The controller is being bypassed either by a welded contactor or a critical malfunction in the controller.

Table 4: Errors Recorded During Run-Time Diagnostics

2. Data Logging

The TSE1000/TSE550/TSE600 controller keeps track of the operating conditions of the truck for later use. Some of the items it tracks are the battery capacity (for use in BDI) and various times relating to the truck's operation.

Battery Discharge	estimate of the usable charge remaining in the battery
Periodic Maintenance Clock	time since last maintenance check
Operating Time	total amount of time power has been on
Lifting Time	total amount of time the pump contactor has been on
Running Time	total time the truck has been out of neutral
SRO Time	total time the SRO switch has been on

Table 5: Data Logging

(1) Periodic Maintenance (PM) Time

This clock keeps track of the time elapsed since the last maintenance on the truck. In order for the system to work properly, the clock should be cleared each time maintenance is performed on the truck.

(2) Operating Time

This clock tracks the total amount of time that the controller has been on. This time cannot be cleared and continues through the life of the controller.

(3) Lifting Time

This clock tracks the amount of time that the lift pump contactor has been on since it was last cleared. If the lift pump contactor is not wired to the TSE1000/TSE550/TSE600 controller (i.e.: if a separate lift pump controller is used), then this clock will always be 0.

(4) SRO Time

This clock keeps track of the amount of time that the SRO (or "dead-man") switch has been on since it was last cleared.

(5) Running Time

This clock keeps track of the amount of time that the truck has been running (i.e., the time a direction has been selected) since it was last cleared.

III. INSTALLATION PROCEDURES

If this is the first time you are installing an TSE1000/TSE550/TSE600, please read through all of the directions before you begin. If you have any questions about installation please call your dealer or contact Navitas Technologies at (519) 725-7871.

Dealer affix stamp here

This part of the manual includes instructions and diagrams for wiring an TSE1000/TSE550/TSE600. It also explains the basics of programming the controller so that it will suit the specifications of the particular truck, battery, contactors, etc. These two sections are essential reading. The final section gives trouble-shooting tips for the problems you might encounter in the installation. (Even though it is a helpful section, we hope you never have to read it.)

You can install the controller by following the steps outlined below. These steps are essential to the proper functioning of your controller and truck. Please follow them with care. Please also check that the other parts of the truck (battery, motor, coils, etc.) are in good working order. We cannot take any responsibility for damage resulting from failure to follow the details of these instructions.

CAUTION: When working with the controller please remember that its capacitors stay charged for years. High voltages may appear on the controller connections even when the battery is not connected. You can discharge the capacitors by connecting the B+ power bar to B- through a resistor, or after the controller is wired, by turning on the key switch with the battery disconnected.

A. BEFORE YOU BEGIN

Before beginning installation, position the truck with its drive wheels raised off the ground and the battery disconnected.

You will need a number of parts to install your controller properly:

1. **Wiring.** A complete set of new wires for the control signals is available with every TSE1000 and TSE550 controller. Although it is possible to use the existing wiring, doing so creates unnecessary risks (because the wiring may have been modified in the past or may be worn).
2. **Contactors.** You can wire the truck using the existing forward, reverse, lift pump and steering pump contactors (as well as field weakening and bypass contactors, if the truck uses them). All the contactors in the truck should have the same voltage.
3. **Accelerator/Potentiometer.** As shipped the controllers are set to use a standard 5000 to 0 Ohm potentiometer. The TSE1000/TSE550/TSE600 will work with any class of potentiometer (log, semi-log, linear) although accelerators with linear potentiometers are easiest to install. The controller will support any power rating ½ watt or larger; however, the system will function best with a mechanically rugged pot. (e.g., 2 watts). If you plan to use the existing accelerator please make sure it is clean and in good working order before you begin. You will find more information on installing different types of accelerators in the section on *Accelerator Configurations* on p. 10.
4. **Fuses.** The TSE1000 and TSE550 require a 10 - 20 Amp fuse mounted on the live side of the key switch. They also require adequate main fuses from the battery (400 Amp for the TSE1000 and 250 Amp for the TSE550).

5. **Miscellaneous.** You will also need thermal compound, 4 bolts (3/8"), miscellaneous wire (at least 18 gauge) and connection hardware (e.g. connector bars).

B. MOUNTING THE CONTROLLER

After removing the existing controller, its wiring, and all unnecessary accessories, locate a suitable mounting position for the TSE1000/TSE550/TSE600 and contactors. The mounting surface must be flat and large enough to ensure good heat dissipation.

- Remove paint from truck surfaces and apply a light coat of thermal transfer compound.
- Drill 4 holes using the mounting template included with the controller as your guide for bolt spacing. Use the slots located in the four corners of the base of the controller to bolt it in place. **You must use four bolts, equally torqued** to secure the controller.

C. WIRING

NOTE: Most of the terminals are protected against incorrect wiring. However, the controller is **NOT** protected against reversed battery connection.

You may refer to *Figure 8: Connection Diagram (4T Motor)* p. 24 for more help.

1. Connecting Power

NOTE: Do not connect power to the controller until the entire installation is completed.

- Run a wire (at least 18 gauge) from a convenient B+ source, after the emergency disconnect, through a 10 - 20 Amp in-line or dash mounted fuse to the live side of the key switch.
- Connect the **negative** battery cable to the main connector bar on the controller labeled **B-.**

2. Connecting the 8-Pin Harness

- Plug the 7-wire harness onto the lower set of eight (8) pins on the controller. Make sure that the orange wire is connected to the last pin on the left. (See Diagram I: Controller Wiring).
- If you are using polarized contactors please ensure that the coils are properly polarized as you connect them.

NOTE: Please note that many other controllers switch the positive side of the contactor coils, but the TSE1000 and TSE550 switch the negative side. Be sure to check connections when using existing contactors.

a) Key

The steps which follow instruct you in connecting several wires to the switched side of the key switch. Because of the number of wires involved, you may wish to install a connector bar between the key switch and the controller.

- Connect the *red* wire to the switched side of the key switch. The key switch provides battery voltage to the control circuits.

b) Bypass

Because of the efficient performance of the TSE1000/TSE550/TSE600, bypass (sometimes called 1-A) is an unnecessary feature (see Bypass (1-a) Contactor*; p. 12). If you are currently using bypass on your truck we strongly recommend that you give the truck a trial period without this feature to compare the results. Be sure to insulate and secure the end of the green wire during this time.*

If you wish to continue using bypass you may connect it as follows.

- Connect the positive (+) side of the bypass contactor coil to the switched side of the key switch.
- Connect the *green* wire to the negative (-) side of the bypass contactor coil.

c) Field Weakening

If you are not using field weakening:
- Clip and insulate the end of the *yellow* wire and proceed to step d).

If you are using field weakening:
- Connect the *positive* (+) side of the field weakening contactor coil to the switched side of the key switch.
- Connect the *yellow* wire to the negative (-) side of the field weakening contactor coil.

d) Forward

- Connect the positive (+) side of the **forward** contactor coil to the switched side of the key switch.
- Connect the *orange* wire to the negative (-) side of the forward contactor coil.

e) Reverse

- Connect the positive (+) side of the **reverse** contactor coil to the switched side of the key switch.
- Connect the *gray* wire to the negative (-) side of the reverse contactor coil.

f) Steering

- Connect the positive (+) side of the **power steering** contactor coil to the switched side of the key switch.
- Connect the *blue* wire to the negative (-) side of the power steering contactor coil.

g) Lift Pump

- Connect the positive (+) side of the pump contactor coil through the lift and tilt switches (in parallel) to the switched side of the key switch.
- Connect the *brown* wire to the negative (-) side of the pump contactor coil.

All models use a lift pump to control the main lift, but some also use an auxiliary pump to control steering, tilting and side shifting. If you are installing the controller (without a pump controller) in one of these models, connect it as follows:

- Connect the pump contactor coil to the lift switch.
- Connect the auxiliary pump as in the instructions for the steering pump.

3. Connecting Input Switches

- Plug the 9-wire harness onto the upper, right-hand set of pins. Make sure that the *white/black* wire is connected to the last pin on the right. (Refer to *Connector Pins* on p. 25)

a) Service Brake/Accelerator Switch

The *white/black* wire is used to connect both the service brake switch and the accelerator switch. If the truck has a brake switch, it must be a normally-closed switch (i.e., open when you the service brake is on). If the truck has an accelerator switch, it must be a normally-open switch (i.e. closed when you step on the accelerator). If the truck has both switches they must be connected in series. The *white/black* wire must then be connected to the switched side of the key switch.

NOTE: The *white/black* wire **must be connected** to the switched side of the key switch even if you do not use a brake switch or accelerator switch. The controller will not operate without this connection.

b) SRO

The "static return to off" switch is connected according to the class of truck as follows:

Riders - run the *white/red* wire through the emergency brake switch (if you have one) and the seat switch, and connect it to the switched side of the key switch.

Stand-ups - run the *white/red* wire through the emergency brake switch (if you have one) and the dead-man switch, and connect it to the switched side of the key switch.

Walkies - run the *white/red* wire through the emergency brake switch, usually mounted at the bottom of the main control arm, and connect it to the switched side of the key switch.

c) Speed Limit Switches

The use of limits is optional.

If you are not using limits:
- Clip and insulate the ends of the *white/brown, white/orange,* and *white/purple* wires and proceed to the next step.

If you are using limit switches, they should be connected according to the class of your truck as follows:

Riders: run the *white/brown* wire through the switch for limit 1 and connect it to the switched side of the key switch. Run the *white/orange* wire through the switch for the second limit and connect it to the switched side of the key switch. Run the *white/purple* wire through the switch for the third limit and connect it (you guessed it) to the switched side of the key switch.

Stand-ups: follow the instructions for riders.

Walkies: (NOTE: the controller parameters must be set with the ProBit to support the belly-button switch) Run the *white/brown* wire through the **belly button** switch and connect it to the switched side of the key switch. Limit 2 can be used to reduce speed when the platform is raised and the driver is walking. Run the *white/orange* wire through the appropriate switch and connect it to the switched side of the key switch. Clip and insulate the end of the *white/purple* wire.

d) Forward

- Locate the **forward** switch in the directional control and connect its live side to the switched side of the key switch.
- Connect the *white/yellow* wire to the switched side of the forward directional switch.

e) Reverse

- Locate the **reverse** switch in the directional control and connect its live side to the switched side of the key switch.
- Connect the *white/gray* wire to the switched side of the reverse directional switch.

f) Accelerator

- Connect the *white/green* wire to one side of the **accelerator/**potentiometer.
- Connect the *white/blue* wire to the other side of the **accelerator/**potentiometer.

NOTE: The TSE1000 and TSE550 are set up for 5K - 0 ohm linear potentiometers (where 5K is rest and 0 is full speed), but other potentiometers can be used as well. If you are using a non-linear pot make sure that the resistance at half accelerator is greater than 2500 Ohms. If it is less than this level the truck will be jumpy. See *Accelerator*; p. 8 for further assistance.

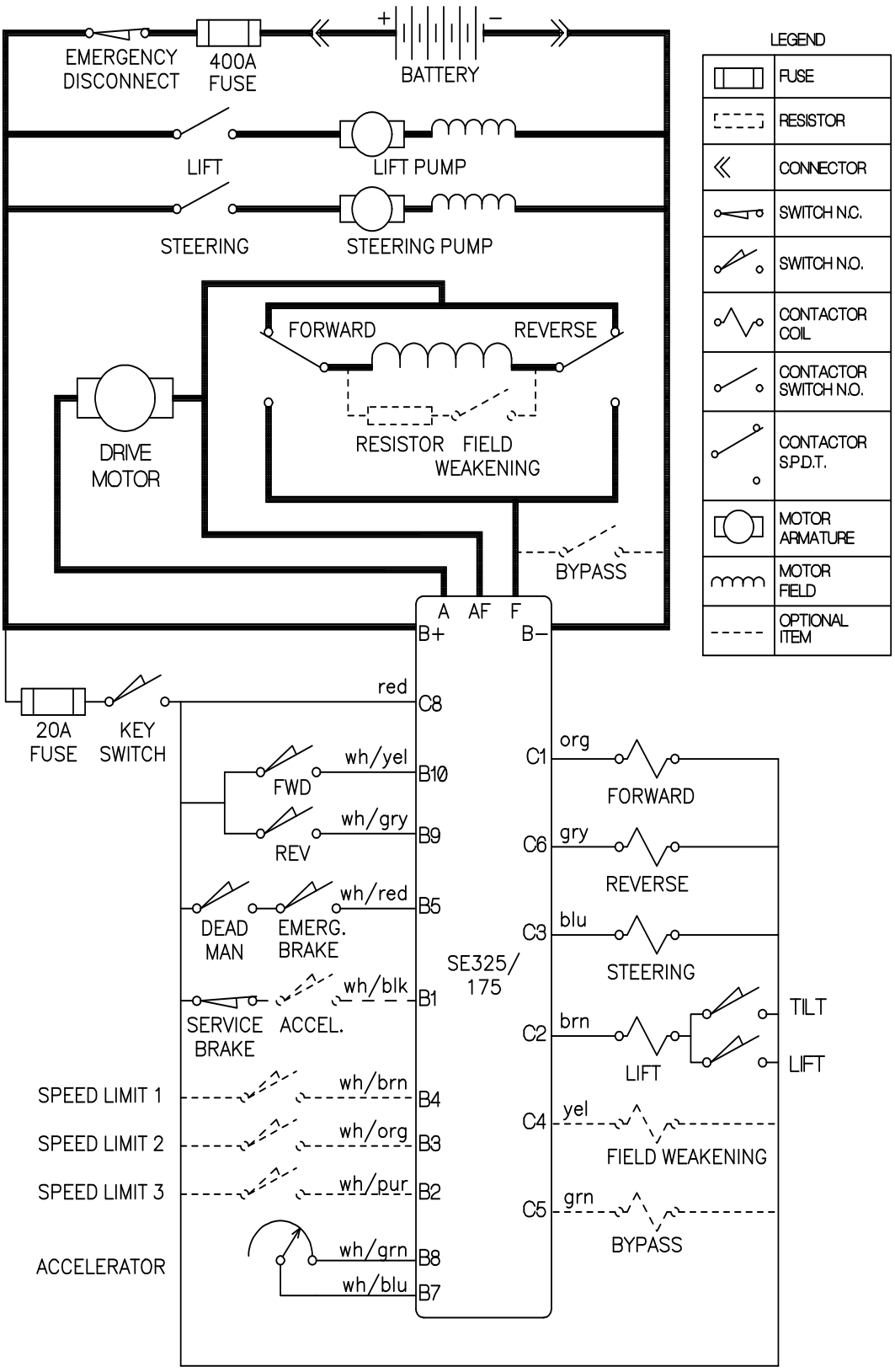


Figure 8: Connection Diagram (4T Motor)

4. Wiring Harness Identification

	I/O	DESCRIPTION	WIRE COLOR
A5	BUS		N/A
A4	BUS		N/A
A3	BUS		N/A
A2	BUS		N/A
A1	BUS		N/A
B10	INPUT	forward input	white/yellow
B9	INPUT	reverse input	white/gray
B8	INPUT	accelerator 1	white/green
B7	INPUT	accelerator 2	white/blue
B6		not used	N/A
B5	INPUT	SRO circuit	white/red
B4	INPUT	speed limit 1	white/brown
B3	INPUT	speed limit 2	white/orange
B2	INPUT	speed limit 3	white/purple
B1	INPUT	brake/accelerator	white/black
C1	OUTPUT	forward contactor	orange
C2	OUTPUT	lift contactor	brown
C3	OUTPUT	steering contact	blue
C4	OUTPUT	field weakening contactor	yellow
C5	OUTPUT	bypass contactor	green
C6	OUTPUT	reverse contactor	gray
C7		not used	N/A
C8	INPUT	key input	red

Table 6: Wiring Harness Pin Identification

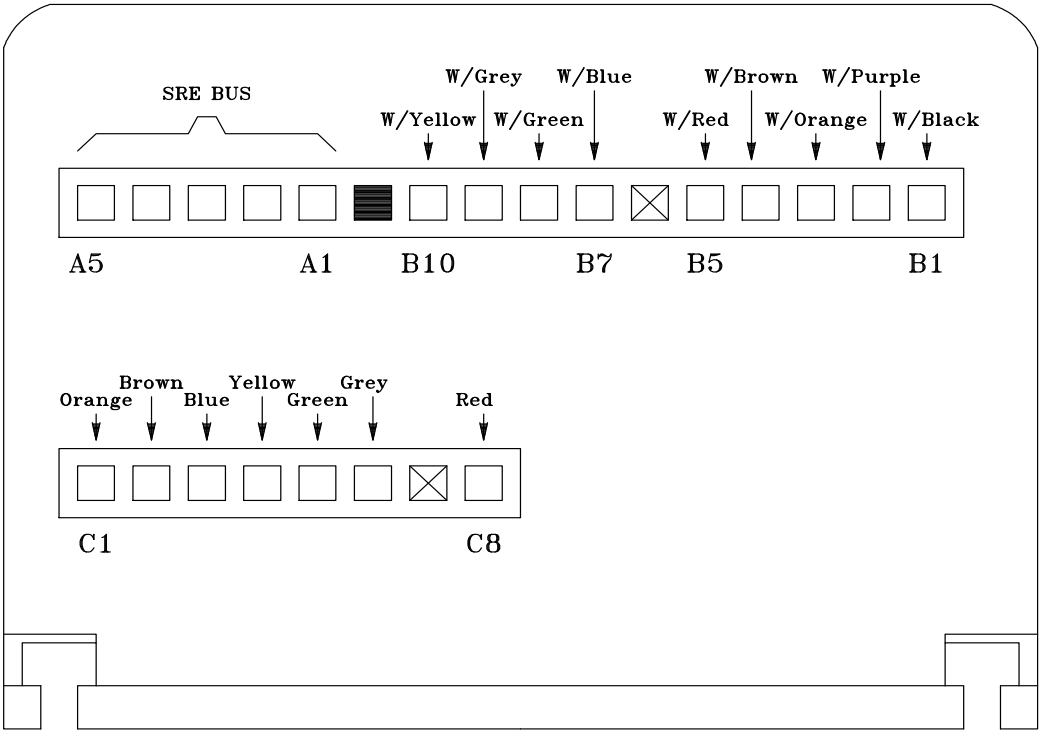


Figure 9: Connector Pins

5. Power Cables

Before connecting the power cables, you need to know what kind of motor you have. The most common motor is 4T (meaning it has four terminals); however, the TSE1000/TSE550/TSE600 supports 3T, 5T and 6T motors as well.

3T: Wire the motor as in the *3T Motor Wiring Diagram*; page 27.

4T: Wire the motor as in the 4T Motor Wiring Diagram, page 30 and refer to the step by step instructions for the 4T motor given on page 29.

5T: Wiring for 5T motors takes some interpretation because motor manufacturers aren't consistent in the way they label the terminals and because there is more than one way to connect the two fields. See *5T Motors*; page 31 for complete details.

6T: These motors are also not labeled consistently. Complete details are given in *6T Motors* on p. 35.

NOTE: An emergency battery disconnect device and a main fuse (400 Amp for the TSE1000 and 250 Amp for the TSE550 is recommended) must be used between the battery positive (+) and the controller.

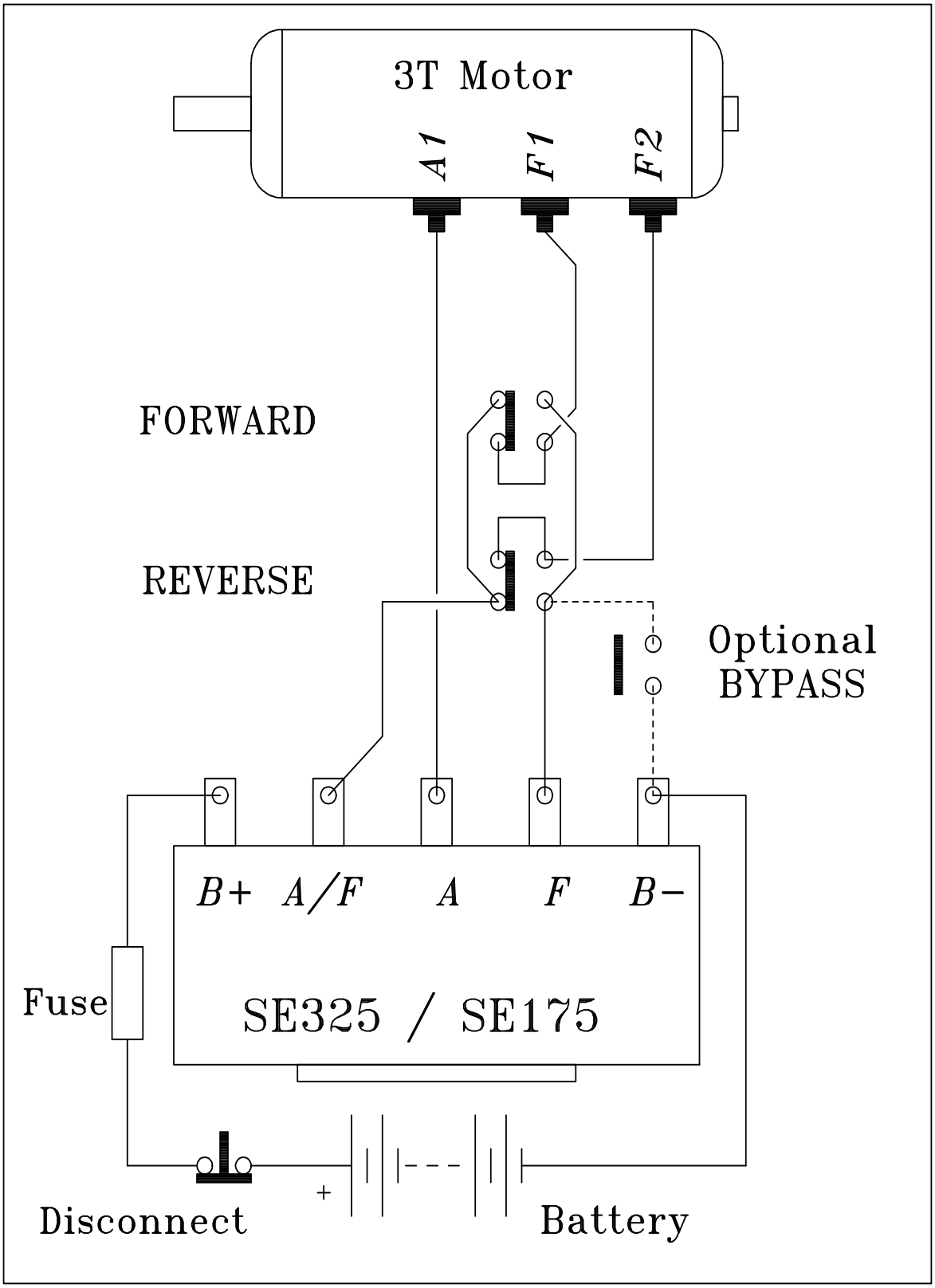


Figure 10: 3T Motor Wiring Diagram

a) 3T Motor

b) 4T Motors

The following instructions give the general steps for connecting power cables**.** Please see the *4T Motor Wiring Diagram* on p. 30 for further assistance.

1. Connect the **motor armature** (the **A1 terminal**) to the center power bar, marked **A** on the controller.

2. Connect the **A2** terminal to the power bar marked **A/F** on the controller.

3. Connect **F1** to the common terminal of the **forward** contactor (see the diagram below).

4. Connect **F2** to the common terminal of the **reverse** contactor (see the diagram below).

NOTE: If the truck travels in reverse when you select forward, interchange these two connections.

5. Connect the normally closed side of the **forward** and **reverse contactor block** to the power bar marked **AF** on the controller.

6. Connect the normally open side of the **forward** and **reverse contactor block** to the power bar marked **F** on the controller.

7. If you are installing a **bypass contactor,** connect it between the normally open side of the **forward** and **reverse** contactor block and the **B-**terminal on the controller. If the truck has been using bypass you must double check this routing since your old system may have connected the bypass contactor at B+, instead of B- as in the TSE1000/TSE550/TSE600.

2. If you are using a **field weakening** contactor connect it across the forward and reverse contactors at their common poles.

3. Connect the positive (+) battery cable to the power bar marked **B+** on the controller and connect the negative (-) battery cable to the power bar marked **B-** (if you have not already done so).

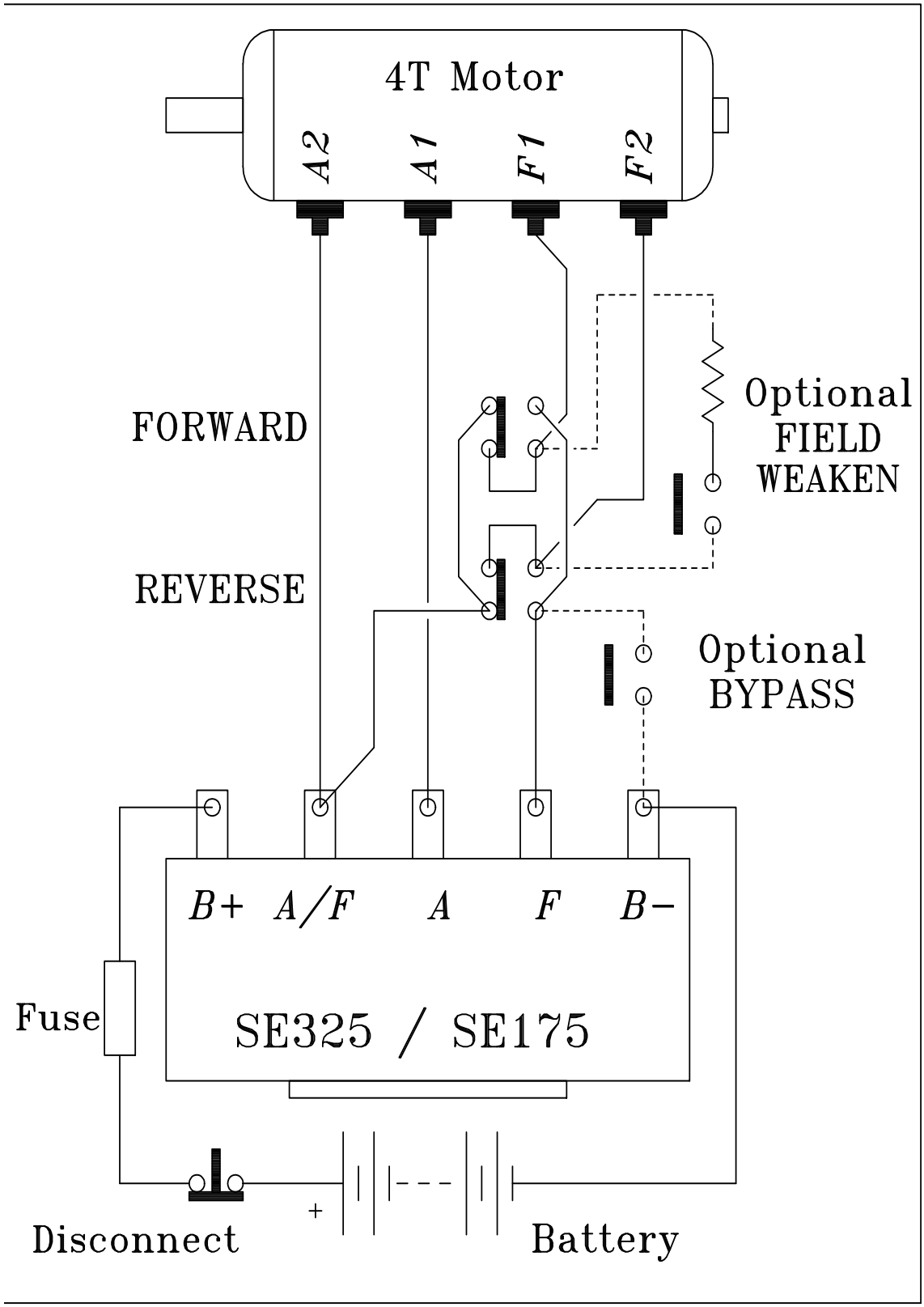


Figure 11: 4T Motor Wiring Diagram

c) 5T Motors

You face two problems when wiring a 5T motor. First of all, motor manufactures are not consistent in labeling 5T motors. Secondly, there are several different ways to connect the fields together. This section discusses a method of verifying the terminal labels, and a way of choosing an arrangement for field connections. However, **if you are doing a retrofit, we recommend that you connect the fields as they were.**

5T motors have two fields that share a common terminal. These motors usually appear in one of two configurations:

(1) Fields for Direction: in European trucks (predominantly), one field is used for the forward direction and the other field is used for the reverse direction. In this configuration, field weakening cannot be used.

(2) Fields for Weakening: in North American trucks (predominantly), the fields are used in combination for field weakening.

After choosing a configuration, you must determine how the terminals are connected to the fields and then choose a field configuration.

(1) Fields for Direction.

1. Choose the terminal which you *think* is shared by both field windings. Label this terminal "F2". If you are not sure which is which, you can guess. In step 7 you will be able to tell whether or not you chose correctly.
2. In the same way you can make a guess for the F1 and F3 terminals and label them. Wire the truck as shown in the *5T Motor Wiring Diagram (Fields for Direction)*, p. 33. Review the instructions for connecting the 4T motor if necessary.
3. After completing the wiring, check to make sure the connections are correct, especially around the forward and reverse contactors. Plug in the battery and turn on the key switch. You should hear the forward contactor and then the reverse contactor pull in. If you do not hear any clicking, refer to section *F. Installation Problem Identification*, p. 44.
4. **Before testing the truck,** set the parameters described in section *Programming the Controller To Suit the Truck*; p. 41.
5. With the truck still on blocks, power up the controller. **Slowly** "drive" the truck in the forward and the reverse directions to make sure the wheels spin properly.
6. If the truck does not run in either direction, check your wiring, especially around the contactors. If you cannot correct the problem in this way refer to section *F. Installation Problem Identification*, p. 44.
7. If the truck only runs in one direction, then your initial guess on the common terminal (the one you labeled "F2") is wrong. Choose another terminal and repeat the steps starting at 2 above.
8. If the wheels spin backward when the direction selector is forward, then F1 and F3 are mixed up and you will have to interchange them. Disconnect the battery with the key switch on (to discharge the capacitors), and then turn the key switch off. Switch the wires on F1 and F3 and re-lable the terminals. Test the truck again.
9. If the wheels spin forward when the direction selector is forward, the truck is wired correctly.

(2) Fields for Weakening.

1. Choose the terminal which you *think* is shared by both field windings. Label this terminal "F2". If you are not sure which is which you can guess. In step 7 you will be able to tell if this guess is right.
2. In the same way you can guess which terminal is F1 and which is F3 and label them. At this point you should ignore the field weakening contactor and leave F2 unconnected. Wire the truck as shown in the *5T Motor Wiring Diagram (Fields for Weakening)*, p. 34. Review the instructions for connecting the 4T motor if necessary.
3. After completing the wiring, check to make sure the connections are correct, especially around the forward and reverse contactors. Plug in the battery and turn on the key switch. If you do not hear the forward contactor and then the reverse contactor pull in, refer to section *F. Installation Problem Identification* on p. 44.

4. **Before testing the truck,** set the parameters as described in section *Programming the Controller To Suit the Truck*, p. 41.

5. With the truck still on blocks, power up the controller. **Slowly** "drive" the truck in the forward and then the reverse directions to make sure the wheels spin properly.

6. If the truck does not run in either direction, check your wiring, especially around the contactors. If you cannot correct the problem in this way, refer to section *F. Installation Problem Identification*, p. 44.

7. If the wheels spin backward when the direction selector is forward, switch the labels for the F1 and F3 terminals. Disconnect the battery with the key switch on (to discharge the capacitors), and then turn the key switch off. Switch the wires on F1 and F3 and re-test the truck. If the truck still runs backwards, then your guess on F2 was wrong. You will need to begin again at step 2 using another terminal as F2.

8. If you are using field weakening, the contactor may now be connected so that when it is closed F2 is connected to F3. You must set the field weakening parameters (see *Field Weakening*; p. 12) before using the truck.

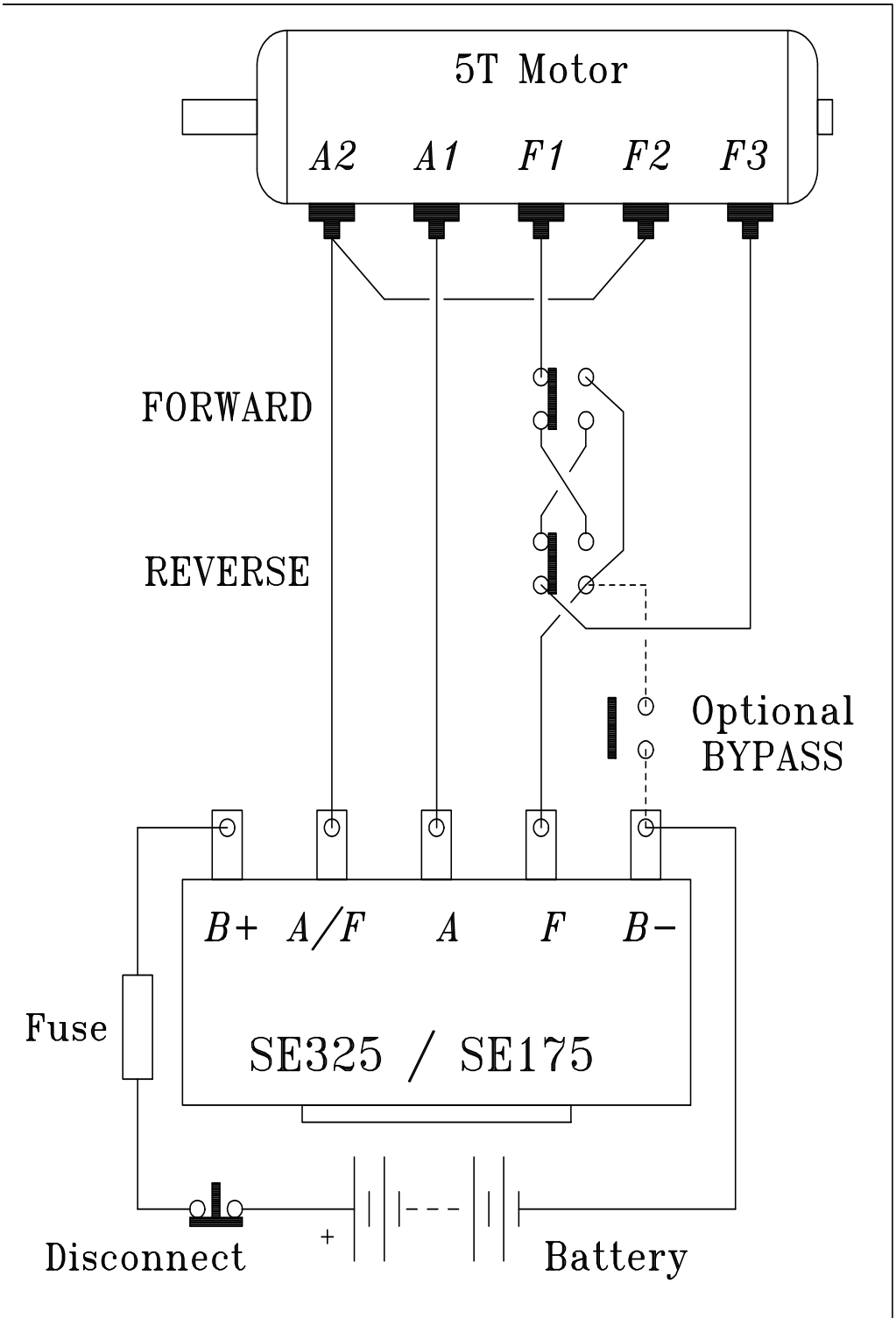


Figure 12: 5T Motor Wiring Diagram (Fields for Direction)

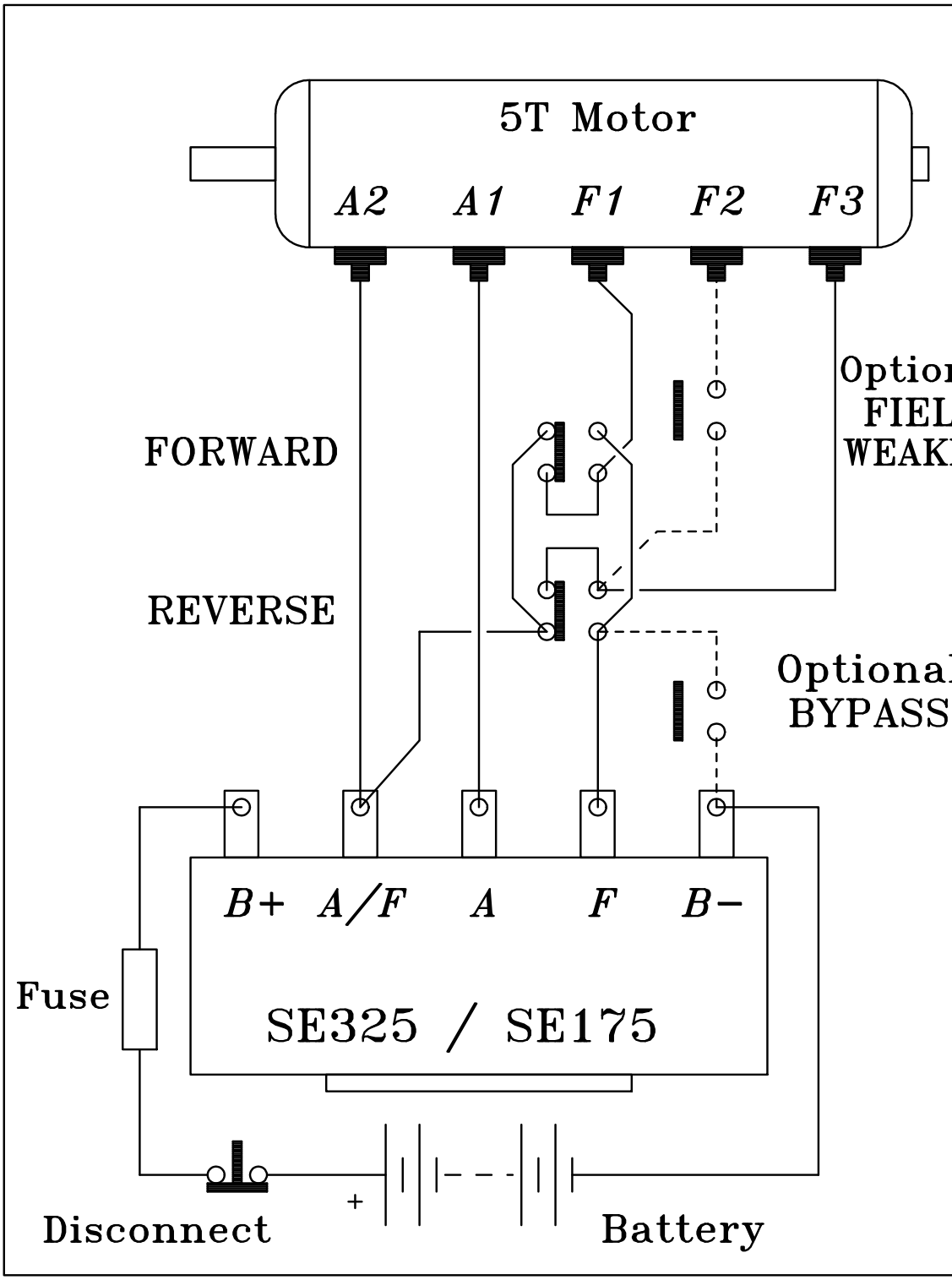


Figure 13: 5T Motor Wiring Diagram (Fields for Weakening)

d) 6T Motors.

A 6T motor has 2 armature terminals and 4 field terminals (because it has two separate field windings). The field terminals are arranged in pairs--one pair for each winding. The first step in installation is to find out how the terminals are connected to the fields.

1. Check the continuity between different pairs of terminals until you find the two pairs of terminals with a low resistance. (If you cannot group the terminals in this way, the field windings likely require service.) Each pair of terminals with low resistance is a field winding.
2. Complete the installation of the controller as though it were a 4T motor by ignoring one pair of terminals (and, hence, one field winding).
3. Disconnect the battery cable with the key on (to discharge the capacitors) and then turn the key switch off.
4. Disconnect the cables from **F1+** and **F1-** and connect them across the other pair of terminals.
5. Power up the controller. Keep the truck elevated while you **slowly** "drive" it in the forward and then the reverse directions. If the wheels spin forward when the direction selector is forward, then the field winding terminal connected to the common pole of the **forward contactor** is **F2+**. Label the F2+ terminal. Label the partner terminal "**F2-**".

   If the wheels spin backward when the direction selector is forward, then the field winding terminal connected to the common pole of the **reverse contactor** is **F2+**. Label the F2+ terminal. Label the partner terminal "**F2-**".
6. Disconnect the battery cable with the key on (to discharge the capacitors).

You have now completed Step 1 and identified the field windings and the terminals. In Step 2 you must decide how to connect the fields to the controller. If you are doing a retrofit, the best option is to connect the fields as they were before.

Usually, the 6T motor allows field weakening without the use of an additional resistor. Less commonly the 6T can be treated like a 4T motor and a field weakening resistor can be used.

These instructions assume no field weakening resistor.

The fields can be connected in 3 configurations[2] as shown in the table below and in figure 14:

Configuration	Torque	Speed
Parallel	med.	high
Single "4T" motor	low	high
Series	high	low

You can use a contactor driven by the controller's "field weakening" output to switch between the single and series configuration (see figure 19) to get maximum torque and maximum speed. If you do not want to use a field weakening contactor, connecting the fields in parallel (*6t Motor Wiring Diagram (Parallel)*) is a good compromise.

1. Select the configuration you wish to use.
2. Disconnect the battery with the key switch on (to discharge the capacitors).
3. If you are using the field weakening contactor, connect the coil as discussed in Field Weakening; page 22.
4. Connect the power cables as shown in the drawing for the configuration you have chosen.
5. Turn off the key switch. Reconnect the battery and turn on the key switch.
6. If you are using a field weakening contactor, use the **ProBit** to set the field weakening parameters as discussed in *Field Weakening*; p. 12.

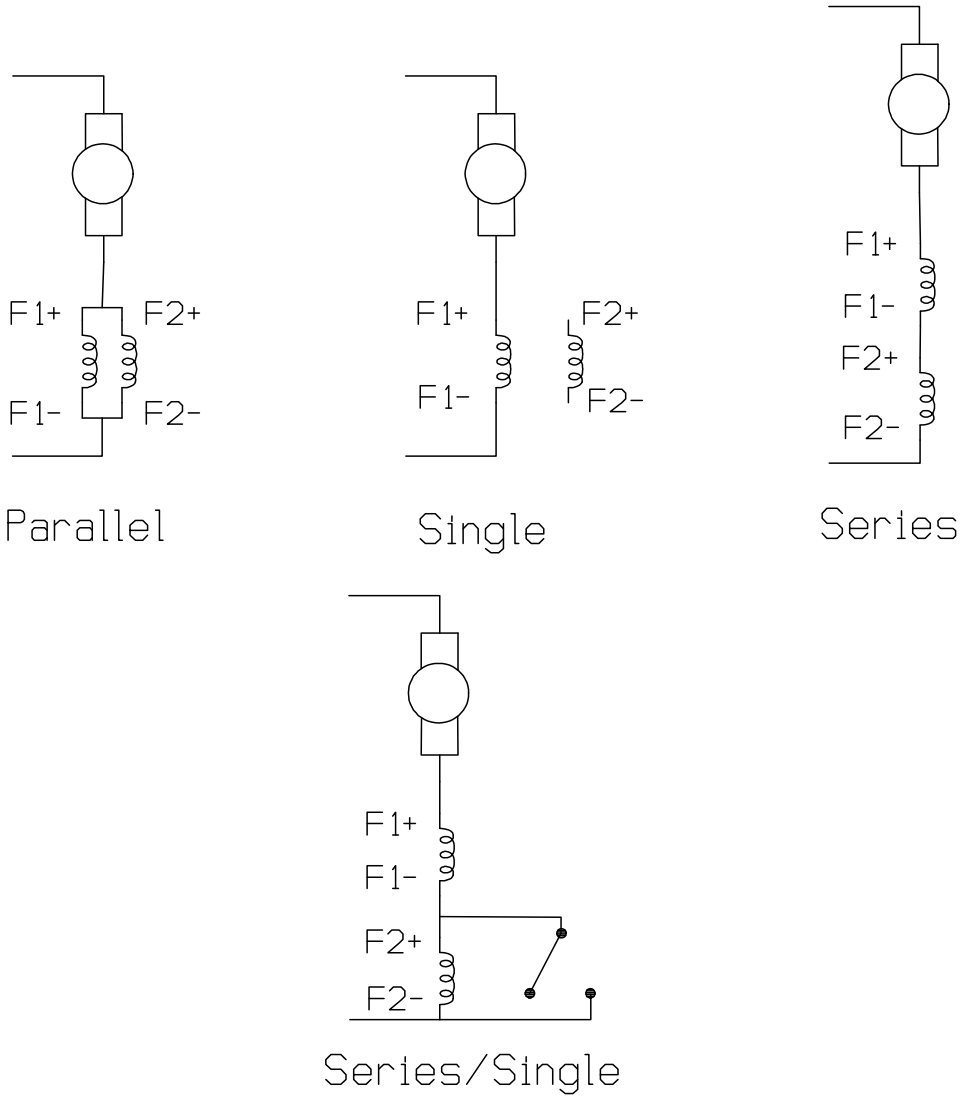


Figure 14: 6T Field Configurations

NOTE: For clarity the direction contactors are not shown.

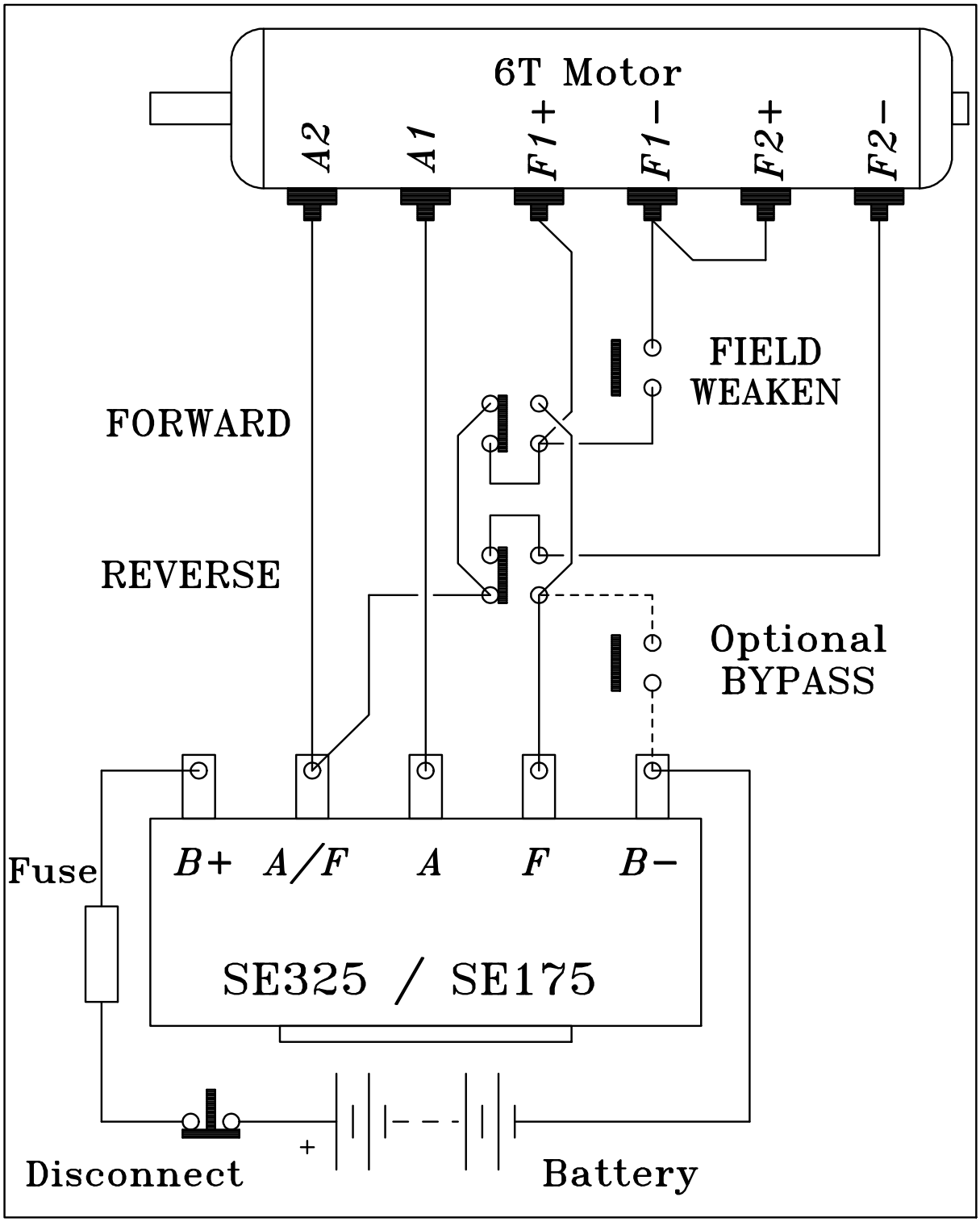


Figure 15: 6t Motor Wiring Diagram (Series/Single)

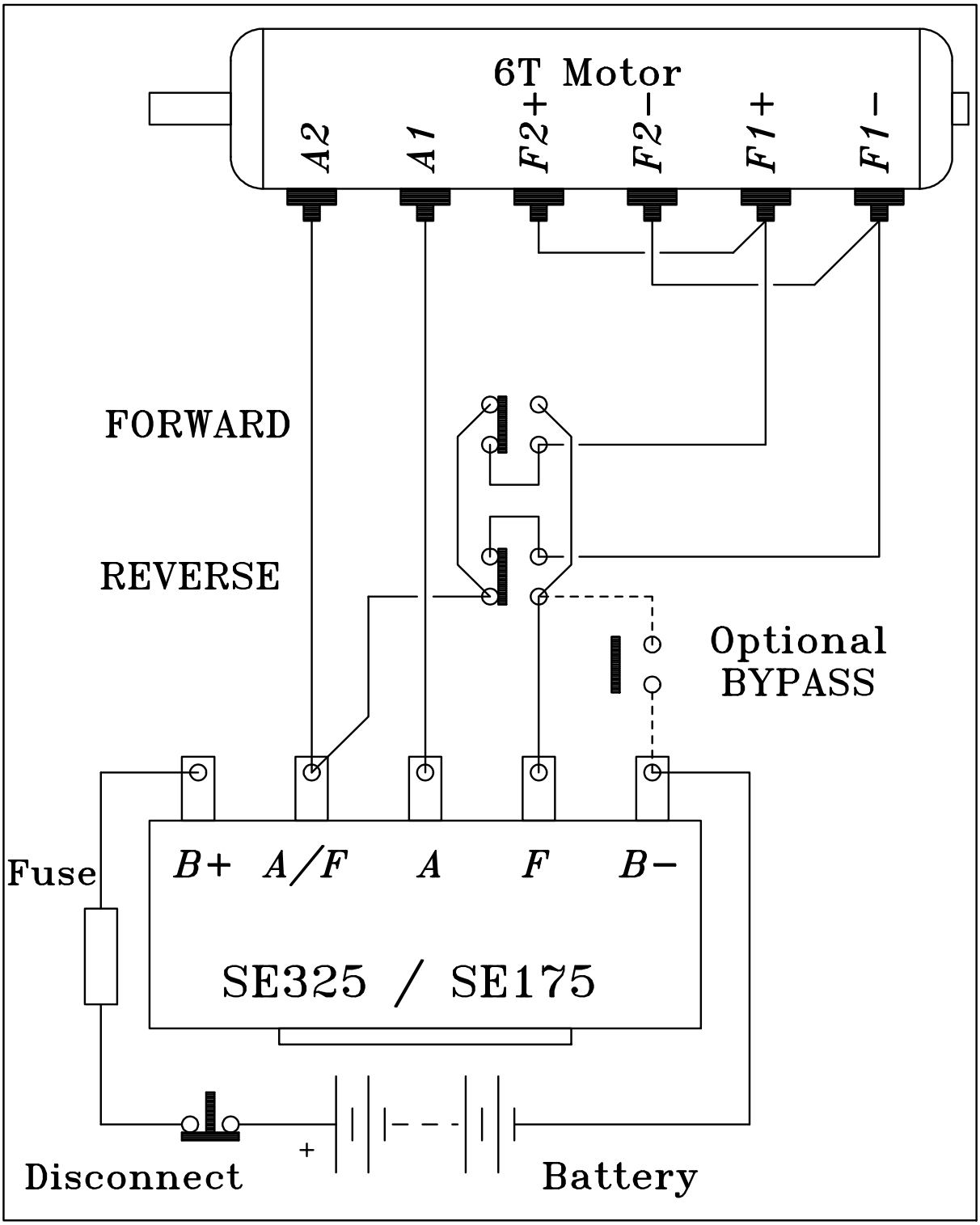


Figure 16: 6t Motor Wiring Diagram (Parallel)

D. PROGRAMMING THE CONTROLLER TO SUIT THE TRUCK

1. Required Settings

Before running the truck, you **must** set the following parameters with the ProBit. For more information on how to set these levels please see the ProBit manual.

Battery voltage: The battery voltage parameter must be set to the voltage rating for the battery. This information is required for the battery discharge interlock to work correctly and for the contactor voltage settings to be correct.

Contactor voltage: As shipped the contactor voltage is set to B+. (In other words, whatever voltage you set for B+ will automatically be set for the contactors.) You can adjust the contactor voltage to the level that is appropriate for the vehicle's contactors. (All the contactors must have the same voltage.) You can also set the contactor hold voltage to a separate, lower level.

Throttle minimum: As shipped the throttle minimum is set to 23% (i.e., your accelerator can be off by 23%). This level gives room for the inadequacies of most accelerators, but it should be adjusted for the specific accelerator you are using. If it is set too low then the controller will always fail the safe-sequencing startup. If it is set too high then you will not have full use of the accelerator. See p. 9, *Throttle minimum and Throttle maximum* for more help.

Throttle maximum: As shipped the throttle maximum is set to 95%. This level will work for most accelerators, but should be adjusted for the specific accelerator you are using. If it is set too low then only part of the accelerator will be used. If it is set too high the controller will never reach full motor voltage, and therefore, never reach full speed. See p. 9, *Throttle minimum and Throttle maximum* for more help.

2. Optional Settings

In addition to these levels, you will probably also want to adjust the following parameters:

Contactor change time: This parameter controls the time it takes the contactors to pull in or out. As shipped this time is set to 1/2 second (so that it will work with even the slowest contactors), but this level gives a noticeable delay between one contactor pulling out and the other pulling in when changing directions. If you have good contactors you should be able to set the change time as low as 0.150 seconds which gives no noticeable delay when changing directions. In general, if this value is set too low the controller will fail diagnostics when switching contactors and if it is set too high there will be a noticeable delay when switching directions.

Plugging strength: As shipped the plugging strength is set to 280 Amps for the TSE1000 and 140 Amps for the TSE550. In almost all cases you will find this to be "soft" plugging (i.e. the truck will coast for a long time before it stops) and you will want to strengthen it. The other setting to adjust is deceleration. This time determines how long the truck will take to reach maximum plugging strength. The default is set at 0.4 sec. See p. 7, *B. Plug Braking* for more help.

Acceleration: The acceleration level lets you set the time it takes to go from 0 volts to full motor output. As shipped the controller is set to 2 seconds. See p. 9, Drive Feel (in section F. Accelerator) for more help.

Top speed: As shipped this parameter is set to 100% of the full motor voltage. You can lower this level if you have an application that requires less than full truck speed.

Speed Limit Cutbacks: If you have connected any of the cutback switches, you should adjust the cutback levels to provide the appropriate top speeds (motor voltages) for each of the cutbacks. The factory preset levels are as follows: cutback 1 is 80% of motor output; cutback 2 is 60%; and cutback 3 is 40%. You can connect each cutback independently to a switch and you can set each cutback level independently to any level of 0%-200%, but you should remember that <u>if more than one switch is closed at the same time cutback 3 will always overrule the others and cutback 2 will always overrule cutback 1.</u> See p. 13, *L. Speed Limit Switches* for more information.

Bypass: If you are using bypass, you should set the bypass pull-in level. This level is the motor voltage at which the bypass contactor will pull in. It can vary between 80% and 100% of battery voltage. You can find a fuller explanation on p. 12 in *J. Bypass (1-a) Contactor.*

Field Weakening: If you are using field weakening you should set the field weakening pull-in and pull-out levels and the bypass pull-in level. Since these levels can be somewhat complicated please see p. 12 *Field Weakening* for a fuller explanation.

3. Programmable Parameters

The following table lists some of the parameters that can be programmed with the ProBit. For a fuller explanation please see the ProBit manual.

Although all of these levels can be changed, we recommend that you change only one or two at a time. One parameter can significantly change other aspects of the truck's performance.

Parameter	Measured By	Range	Preset Level
max. plugging strength for TSE1000	motor current	 0 - 1000 Amps	 280 Amps
for TSE550		0 - 550 Amps	140 Amps
for TSE600		0 – 600 Amps	
acceleration	time to get to maximum motor output	0.1 - 60 sec.	0.4 sec.
deceleration	time to get to maximum plugging current	0.1 - 60 sec.1	0.4 sec.
maximum speed*	% of motor output	0-100%	100%
speed cutback 1*	% of top speed limit	0-200%	80%
speed cutback 2*	% of top speed limit	0-200%	60%
speed cutback 3*	% of top speed limit	0-200%	40%
acceleration level*	time to full motor output	1-10 sec.	2 sec.
limp speed	% of full motor output	0-100%	50%
direction change forgive time	max. time direction switches can remain in neutral (without setting off the SRO)	0.15-1 sec.	0.5 sec.
power steering continuation	continuation of steering power after SRO is set off	0-1600 sec.	5 sec.
bypass threshold	% of motor output	80-100%	95%
bypass pickup delay	time motor output must remain at bypass level	2-10 sec.	3 sec.
field weakening pickup	motor current	10-1000A	115A
field weakening dropout	motor current	10-1000A	230A
current limit: maximum for TSE1000	motor current	 0 - 1000 Amps	 1000 Amps
for TSE550		0-550 Amps	550 Amps
for TSE600		0-600 Amps	600 Amps
current limit: average for TSE1000	motor current	Peak 0 - 1000 Amps	Continuous 325 Amps
for TSE550		0-550 Amps	175 Amps
for TSE600		0-600 Amps	260 Amps
lift interlock	whether or not lift is locked at low battery levels	enable-disable	enable
SRO/lift interlock	whether or not lift is locked when SRO is set off	enable-disable	enable
contactor hold voltage	manufacturer's specified hold voltage	12V-B+	B+
contactor pull-in voltage	manufacturer's specified pull voltage	12V-B+	B+
contactor change time	maximum time allowed for contactor to pull in or out	0.15-1 sec.	0.15 sec.

contactor pull-in time	time spent at pull-in voltage	0 - 10 sec.	0.5
throttle maximum	percentage of full accelerator travel	0-100%	95%
throttle minimum	percentage of deviation from full accelerator rest position	0-100%	23%
throttle polarity	position for 0 Ohms	max.-min.	max.
battery size	specified battery voltage TSE1000/550	24 - 48V	36V
	specified battery voltage TSE600	60 -96V	
bypass on/off	whether or not bypass circuit is used	on - off	off

**Each of these levels can be programmed separately for forward and reverse.*

E. POWERING UP THE TRUCK

Your truck is now ready for use. When you turn power on you should hear the forward and reverse contactors pull in as the controller goes through the startup diagnostics. The most commonly requested settings have been preprogrammed in the controller for your convenience; however, they may be changed with the **ProBit** to suit your preferences.

We hope you enjoy the smoother feel and more reliable performance of your TSE1000 or TSE550. If you have questions that are not answered here please contact your dealer.

F. INSTALLATION PROBLEM IDENTIFICATION

1. Installation Basics

When installing a new controller, you should double check the wiring as you go. Wiring errors are much harder to find later on. The wiring of B+ and B- to the controller power bars is particularly important.

NOTE: Improper wiring of the B+ and B- connections can cause permanent damage to the controller! The controller is not protected against reversed battery connection.

Inserting the Wiring Harness. You can insert the wiring harness connectors upside down if you push hard. Please check the alignment before you resort to brute force. If the connectors are improperly inserted the controller will not work, but no damage should occur.

Checking Error Codes. The TSE1000/TSE550/TSE600 will find most wiring flaws during start-up diagnostics and errors will be reported by the ProBit. The ProBit identifies each error with a code number and an explanation. You can look up the code in the ProBit manual to get the fullest picture of what is happening. Learning how to interpret and act on these error messages will help you to resolve problems quickly.

If the TSE1000/TSE550/TSE600 finds a problem during start-up diagnostics it will not even attempt further tests and the truck will not operate. You can check for error codes with the ProBit. (After you read the error, you should delete it from memory; otherwise, the TSE1000/TSE550/TSE600 will continue to report it.)

2. If the Diagnostics Fail.

The following pages list typical problems which can arise during installation and help you to locate and correct the problem. Along with checking these details you should also ensure that the truck's other components are in good working order (e.g. the battery, the accelerator, etc.)

The only tools necessary for most debugging of an installation are a normal Volt-Ohm Meter, a current meter, and the ProBit. To check the input voltages to the controller, insert a meter probe into the connector with the meter ground lead connected to the B- bar.

PROBLEM: THE TRUCK DOES NOT RUN. DIRECTION CONTACTORS DO NOT PULL IN ON START UP.

1. CHECK: Does the ProBit power up properly?

- If the ProBit does not work check the key switch and its fuse.

  TO TEST: Read the voltage at the controller's **key switch input** (the red wire). You should read full battery voltage when the key switch is on. If you read no voltage temporarily remove all unnecessary accessories from the output of the key switch in case they are overloading the fuse.

2. CHECK: Does the ProBit show a contactor error?

- If you find a contactor error check the **contactor voltage** setting with the ProBit. If the voltage is set too low the controller may not have the power to pull in the contactors.

  TO TEST: Try increasing this voltage.

- Check the forward and reverse contactor wiring to ensure that:

  1) the contactor commons are connected to the field winding,

  2) the normally open sides of the direction contactors are connected to the **F** power bar on the controller
  3) the normally closed sides of the direction contactors are connected to the **A/F** power bar.

  TO TEST: Measure the voltage between B- and the direction contactor commons. If they are connected properly a volt meter will measure full battery voltage. Disconnect the battery, and measure the resistance in three places: between both direction contactor commons, between the normally closed sides of both direction contactors, and between the normally open side of both direction contactors. The ohm-meter should measure nearly zero Ohms (a short) across each of these points.

- Next check the contactor coils. One side of the coils should be connected to the TSE1000/TSE550/TSE600 and the other to the key switch (B+). Note- if there are suppression diodes built into the contactors make sure the coils are polarized properly.

  TO TEST: Check the direction contactor coils with an ohm meter. The resistance should be higher than 5 Ohms.

PROBLEM: THE TRUCK DOES NOT RUN. ONE DIRECTION CONTACTOR PULLS IN ON START-UP.

1. CHECK: Does the ProBit show a contactor error?

- Check the contactor settings--particularly the **contactor voltage** and **contactor change times**. If the contactor voltage is set too high it may cause a contactor coil overcurrent. The contactor change time should be set high enough to allow the contactors to move in and out as they switch from forward to reverse.

  TO TEST: Start with the change time set to 1.0 second or more and then, after passing the start up diagnostics, you can lower it appropriately. As you lower it, leave a little extra time--if you set it too close to the limits of your contactors you will get occasional errors (since contactors do not always change at their fastest). Older contactors in particular need more change time (0.5 seconds or more) while newer contactors can be set quite low (0.150 seconds or faster).

- Next you can check the direction contactor wiring as described in the CHECKS section above.

PROBLEM: THE TRUCK DOES NOT RUN. BOTH DIRECTION CONTACTORS PULL IN PROPERLY DURING STARTUP DIAGNOSTICS BUT DO NOT PULL WHEN A DIRECTION IS SELECTED.

1. CHECK: Is the SRO switch (the dead-man switch) working?

- Check the SRO switch to make sure it is working properly.

  TO TEST: With the truck in NEUTRAL, use a voltmeter to check the voltage between the **SRO input** on the TSE1000/TSE550/TSE600 and negative. If the switch is working properly, the input will measure battery voltage.

2. CHECK: Are the accelerator/throttle parameters set correctly?

- Check the **throttle minimum** setting with the ProBit. If the accelerator/throttle is off a little and does not travel all the way back to rest it seem to be activated all the time (see p. 9, *Throttle minimum and Throttle maximum* for a fuller explanation). When this happens the safe sequence is broken and the truck will not run (see p. 8, Safe Sequencing).

  TO TEST:

  1) Plug in the ProBit and go to the **throttle minimum** menu.

  2) Leave the accelerator/throttle at rest and check the reading for "throttle position" in the ProBit. The ProBit will tell you exactly where the accelerator is sitting.

  3) Now check the ProBit for the setting for **throttle minimum**. If the "throttle position" reading is higher than the **throttle minimum**, then the accelerator will act as if it is always depressed, and the direction contactors will not engage.

  4) Take the reading for "throttle position" and set this value, plus about 5%, as the new **throttle minimum**. (If you set the throttle minimum at exactly the accelerator position, the diagnostics may occasionally fail because many mechanical accelerators do not return to the exact same rest position every time.)

- Check the throttle polarity. If the current accelerator rest position is very high, the throttle polarity may be reversed. In other words, the accelerator/throttle may need 0 Ohms at rest and 5k Ohms at full.

  TO TEST: Use a voltmeter to check the voltage between the throttle 1 pin on the controller and the throttle 2 pin. As you press the accelerator/throttle slowly the meter should travel from roughly 5 volts to 0 volts.

NOTE: The potentiometer always defaults to 5000 Ohms when there is a faulty connection. Therefore, if a wire comes loose when the polarity is reversed the truck will go to full speed.

3. CHECK: Is the wiring for the direction switches OK?

- If the truck passes all of the checks above and the problem remains, check the wiring of the direction switches into the controller.

  TO TEST: Use a voltmeter between the chosen switch input and B-. You should read full battery voltage whenever a direction is selected.

PROBLEM: THE TRUCK DOES NOT RUN. THE DIRECTION CONTACTOR PULLS IN WHEN A DIRECTION IS SELECTED BUT THE TRUCK DOES NOT MOVE.

1. CHECK: Is the **brake/accelerator** switch wired properly?

- Even if you have not connected these switches, check the wiring around the **brake/accelerator** switch. This switch can be a little more complicated than most. If it is wired incorrectly, the TSE1000/TSE550/TSE600 may be disabled and the truck will not move.

  TO TEST: Use a voltmeter to check the voltage between the **brake/accelerator** input pin and B-. Voltage should be equal to full battery voltage.

2. CHECK: Is the **battery voltage** parameter set correctly?

- Check the **battery voltage** parameter to make sure that it is set at the manufacturer's rating for the battery.

  TO TEST: Plug in the ProBit and ensure that the proper battery voltage is set and that the battery on your truck is sufficiently charged for normal use.

3. CHECK: Are the speed limits OK?

- Check all the **speed limit** inputs into the controller. The speed levels for these switches may be set too low or a speed limit input may have been connected accidentally. In either case the truck might not have enough power to start from a stop.

  TO TEST:

  1) Check the voltage between each speed limit (cutback) input and B-. You should read no voltage at these inputs.

  2) If **speed limits** have been wired in, temporarily disconnect them. If the problem disappears when **speed limits** are disconnected, you may have to increase the maximum speed for these inputs. Plug in the ProBit and put the truck up on blocks (so you can see the wheels move at low levels) and try raising the speed limits.

- Check the **maximum speed** setting to make sure it is not too low. If it is too low the truck may not be getting the power it needs to start from a stop.

  TO TEST: Plug in the ProBit and check that the Maximum Speed is not set too low. (This level will be different for each truck and each situation.)

4. CHECK: Is the accelerator/throttle working properly?

- Check the accelerator input on the controller to ensure that the accelerator is working properly.

  TO TEST: Use a voltmeter to check the voltage between the **throttle 1** pin on the controller and the **throttle 2** pin. As you press the accelerator slowly, the meter should travel from roughly 5 volts to 0 volts.

- Check the **acceleration level.** If it is set too high the truck might have a long wait before it will get up to speed.

5. CHECK: Is the motor wiring OK?

- When all else fails, check the motor wiring. The armature or the field circuit may not be correct.

  TO TEST: As you press the accelerator, use a current meter to measure the current into the A1 terminal of the motor. If the reading is greater than 200 Amps there is a short somewhere in the motor.

PROBLEM: TRUCK CANNOT REACH TOP SPEED OR THE TRUCK APPEARS TO BE IN CUTBACK.

1. CHECK: Are the speed limits OK?

- Check all the **speed limit** inputs into the controller. The speed levels for these switches may be set too low or a speed limit input may have been connected accidentally. In either case the truck might not have enough power to start from a stop.

  TO TEST:

  1) Check the voltage between each speed limit (cutback) input and B-. You should read no voltage at these inputs.
  2) If **speed limits** have been wired in, temporarily disconnect them. If the problem disappears when **speed limits** are disconnected, you may have to increase the maximum speed for these inputs. Plug in the ProBit and put the truck up on blocks (so you can see the wheels move at low levels) and try raising the speed limits.

- Check the **maximum speed** setting to make sure it is not too low. If it is too low the truck may not be getting the power it needs to start from a stop.

  TO TEST:

  Plug in the ProBit and check that the Maximum Speed is not set too low. (This level will be different for each truck and each situation.)

2. CHECK: Is the controller in **cutback**?

- Check whether any of the TSE1000/TSE550/TSE600 **cutbacks** have been set off. For example if the battery voltage has not been set properly the controller may calculate a low charge based on that information. It will then cut the truck back to "limp mode".

  TO TEST:

  Plug in the ProBit and go to the **cutback**s menu. The ProBit will tell you whether the truck is in any kind of cutbacks. If it appears to be in cutback because of low battery charge check your battery voltage parameter to make sure it was set correctly.

3. CHECK: Is the motor wired properly?

- If you are working with a 5T or 6T motor double check that the fields are wired correctly. These motors can be wired with multiple fields parallel (for maximum speed) or with multiple fields in series (for maximum torque).

  TO TEST: Review the wiring instructions outlined on p. 31 for *5T Motors* and on p. 35 for *6T Motors.*

PROBLEM: A DIRECTION CONTACTOR PULLS IN ON STARTUP AND REMAINS IN.

1. CHECK: Are the contactors OK?

- Check contactor coil wiring to ensure that the contactor connections to the controller are not shorted to negative.

  TO TEST: Use an Ohm-meter to check between B- and each of the contactor coil terminals. You should measure a very high resistance (i.e. no short circuits).

- Check for sticky contactor tips.

2. CHECK: Is the battery connected to the controller properly?

- Check the connection of B- to make sure that it is not connected to both the B+ and the B- bars on the controller.

PROBLEM: BOTH DIRECTION CONTACTORS COME IN SIMULTANEOUSLY UPON POWER-UP.

1. CHECK: Are the direction contactor coils OK?

- Check the direction contactor coil inputs into the controller to see if they are shorted to negative.

  TO TEST: Set the Ohm-meter to the low resistance scale and check the reading between each contactor coil terminal and B-. If you read 0 Ohms the coil is shorted to negative.

- Recheck coil wiring.

  TO TEST: Run through the installation instructions and diagrams on pages 26 to 39.

2. CHECK: Is the battery connected to the controller properly?

- Check the connection of B- to make sure that it is not connected to both the B+ and the B- bars on the controller.

PROBLEM: THE TRUCK ACCELERATES PROPERLY AND APPEARS TO WORK UNTIL IT REACHES A HIGH SPEED, AT WHICH POINT THE TRUCK CUTS OUT.

1. CHECK: Is **bypass** enabled even though the truck does not have a bypass contactor?

- Check the **bypass** parameter to make sure it is not enabled. If the bypass is enabled when the truck has no bypass contactor, when the controller reaches a high output it will attempt to pull in a non-existent bypass contactor and will shut itself down. (NOTE: This problem may occur in only one direction because of the way the bypass settings have been configured).

  TO TEST: Plug in the ProBit and go to the **bypass** menu. You can read there whether or not this feature is enabled.

PROBLEM: THE TRUCK WORKS, BUT ONLY IN ONE DIRECTION.

1. CHECK: Does the forward contactor pull in when forward is selected (and reverse when reverse is selected)?

- Check the direction switch inputs to the controller to make sure they are properly connected.

  TO TEST: Use a voltmeter to measure the voltage between each input and B-. You should read full battery voltage.

- Check the direction contactor connections to the motor Field windings to ensure that the **A/F** bar is connected to the normally closed side of the direction contactors.

2. CHECK: Is **field weakening** working properly?

- Check whether **field weakening** is installed properly, if you have wired it in.

  TO TEST: Temporarily disconnect the **field weakening contactor** and recheck the operation of the truck. If the truck works in both directions without field weakening, check that the common terminal and normally open terminal of the field weakening contactor are connected to the common terminals of the direction contactors.

3. CHECK: Are the motor fields wired properly?

- Double check the motor wiring, especially if you are working with a 5T or 6T motor (see the *Power Cables* section, pages 26 to 39). If the field windings are not polarized correctly, one field winding may cancel the other in one or both directions

  TO TEST: Place a current meter on the **A** terminal of the controller (leading to the A1 terminal on the motor). Select the direction that is not working and press on the accelerator/throttle. If you get a high current reading then the fields are canceling one another.

PROBLEM: THE CONTROLLER PASSES STARTUP DIAGNOSTICS, BUT WHEN A DIRECTION IS SELECTED THE DIRECTION CONTACTOR AND POWER STEERING PUMP CONTACTOR BOTH COME IN AND IMMEDIATELY FALL OUT AGAIN.

1. CHECK: Is the steering pump contactor OK?

- Check for shorts in the power steering pump contactor coil.

  TO TEST: Use an Ohm-meter to measure the resistance across the coil. You should read more than 5 Ohms.

2. CHECK: Is the **contactor voltage** parameter set correctly?

- Check whether or not all the contactors voltage setting will work for all the truck's contactor coils. If the truck uses contactors with different voltages the contactor voltage that you have set may be OK for the direction contactors, but too high or too low for the pump contactor coils. In this case you should replace the contactors so all of them have the same voltage. (You can try setting the contactor coil voltage somewhere in between the different coil voltages to see if you can find a voltage that works, but we strongly recommend that you use contactor coils with the same rating.)

PROBLEM: THE TRUCK RUNS BUT PLUGGING IS MUCH TOO HARSH OR MUCH TOO SOFT.

1. CHECK: Is the **A/F** bar on the controller wired properly?

- Make sure that the **A/F** bar is properly connected to the A2 terminal on the motor AND to the normally closed terminal of both direction contactors.

2. CHECK: Are the plug braking parameters set correctly?

- Check the setting for **plug braking** strength and decceleration. You may be able to raise or lower these levels to improve the feel. See section *B. Plug Braking*, p. 7 for more explanation on parameters that can affect plug braking.

If problems persist and cannot be resolved please contact your nearest authorized NAVITAS dealer for additional support. Before calling, please ensure that you have thoroughly checked all wiring and followed any appropriate steps recommended above.

IV. ADJUSTING TRUCK PERFORMANCE

The TSE1000/TSE550/TSE600 is highly programmable. The feel, performance and some interlocks are adjustable to fit the individual truck and its operating conditions. This adjustment is accomplished through the use of the **ProBit**. The **ProBit** allows the installer to adjust the programmable features of the controller's operation. Detailed instructions on the use of the **ProBit** to adjust the controller can be found in the **ProBit** user's manual. For more a summary of the programmable parameters see the chart on page 42.

A. DRIVING FEEL

The parameters related to drive "feel" are set in the "performance" section of the **ProBit**. The speed and acceleration of the controller can be set independently for forward and reverse.

1. Speed and Acceleration

The top speed of the truck (motor voltage) can be set as a percentage (0-100%) of maximum possible speed (motor voltage). You can set separate levels for forward and reverse. In most cases you will want to set this to 100%.

Although this section repeatedly discusses "speed" control, motor controllers cannot directly control the speed of a vehicle: speed is controlled as a function of the applied motor voltage. A particular voltage will not always result in the same speed. Conditions like load and grade will change the speed that is possible for a given voltage.

Acceleration is defined in terms of time. An acceleration of two seconds means that it will take two seconds to advance from stop to full speed. Again, as with speed, the acceleration for forward and reverse can be set at different levels.

2. Braking

Plug braking strength is set as a level of motor current. Under most circumstance the default setting of 280 Amps for the TSE1000 and 140 Amps for the TSE550 will give soft plugging. You will likely want to increase this value. However, you should increase this time gradually since settings that are too high may generate very large torque's.

3. Speed Limits (Cutbacks)

The TSE1000/TSE550/TSE600 provides three speed cutbacks for general use. Each cutback is set to a different percentage of maximum speed (motor voltage). (The factory defaults are 80% for cutback 1, 60% for cutback 2, and 40% for cutback 3.) Cutback levels may be set from 0% to 200% of the maximum speed (motor output) you have set. When a cutback is set over 100% it will act as an overdrive. Acceleration times will shift directly to cutback conditions (i.e. if acceleration is set at 2 seconds, in cutback the truck will reach the cutback voltage in 2 seconds.)

The cutbacks have a built-in priority. If more than one switch is activated at the same time, the level for cutback 3 will always override the other two and the level for cutback 2 will always override cutback 1. For this reason, you are safest to set cutback 3 as the lowest level and cutback 1 as the highest.

B. TIME DELAYS

Several programmable time delays also affect the operation and "feel" of the truck.

1. Contactor Change Time

The **contactor change time** is the maximum time allowed for the contactors to pull in or pull out. This delay helps the diagnostics to work properly. Whenever a contactor pulls in or out the controller measures the time it takes. If a contactor has not pulled in the time you have set, the controller will send out an error code. The **contactor change time** also helps

to control cold switching. Whenever a contactor is switched the controller temporarily shuts off voltage to the contactor until the change time elapses.

As shipped the **contactor change time** is set to 1/2 second which should be long enough for even the slowest contactors. This length of time will, however, result in a noticeable delay as the controller waits for the contactors to change. Where possible you will want to change shorten this time to give a smoother feel to direction changes. You can set the **contactor change time** as low as 0.150 seconds (which gives no noticeable delay) if you have contactors that are new or in good repair.

2. Direction Change "Forgive" Time

The controller has an adjustable "forgive" time to allow the driver to brake (plug braking) by changing directions. If the direction switches stay in neutral for longer than this "forgive" time the driver must go through the startup sequence again before the controller will produce an output.

3. SRO Debounce Time

The **SRO debounce time** is the maximum time that the SRO (dead-man) switch can be disconnected without setting off the SRO protection. Normally, whenever the SRO switch is disconnected the TSE1000/TSE550/TSE600 will return the truck to neutral. The **SRO debounce time**, however, allows the SRO to be disconnected momentarily, for instance when the driver shifts position or bounces from the seat. This time is set at 0.255 seconds.

4. Power Steering Continuation

After the direction switches have returned to neutral or an SRO is set off the steering pump contactor is left on for a preset time to allow powered steering while the truck may be coasting. This time may be adjusted to suit individual preferences.

V. SERVICING YOUR TRUCK AND CONTROLLER

1. Trouble-Shooting

The table below gives a point-form list of some of the problems and causes a lift truck might experience. In general, these problems will only occur if wiring has come loose or been changed, or if components are wearing out.

If you require installation trouble-shooting please see section *F. Installation Problem Identification* beginning on page 44. Some of the causes described here are explained in more detail in that section.

SYMPTOMS	POSSIBLE CAUSES
Truck does not run. Direction contactors do not pull in on startup.	Truck/controller may not be wired correctly. Check the wiring (pages 26-39). Contactor coils may be shorted. Check the coils with an Ohmmeter. Contactor pull-in voltage or hold voltage may be set too low. Check the contactor pull in and hold voltages (see p. 41).
Truck does not run. Only one direction contactor pulls in on startup.	Truck/controller may not be wired correctly. Check the wiring (pages 26-39). Contactor coils may be shorted. Check the coils with an Ohmmeter. The contactor change time may be set too low. Check and increase if necessary (see *Programming the Controller To Suit the Truck,* p. 51).
Truck does not run. Both direction contactors pull in during the startup diagnostics but not when a direction is selected.	The direction selection switches may be wired incorrectly or they may be faulty. Check the wiring and test the switches. The throttle minimum may be too low so that the startup sequence is not being satisfied. Check the setting and make necessary corrections (see *Programming the Controller To Suit the Truck,* p. 51). Throttle polarity may be backwards. Verify the throttle polarity. The SRO may not be satisfied. Check the SRO switch and wiring. The startup sequence may not be satisfied. Double check that the controls are being activated in the correct order.
Truck does not run. Direction contactor pulls in when a direction is selected but the truck does not move.	Brake switch may not be satisfied. Check the wiring and switch for the brake. Maximum speed may be set too low. Check and adjust the maximum speed.
Truck occasionally fails to change direction.	Direction switches may be wearing out. Check and replace if necessary. Contactor change time may be a little too short. Check and lengthen if necessary (see *Programming the Controller To Suit the Truck,* p. 51).
Truck runs for five minutes and then loses the top end (cuts back) and the lift refuses to operate.	Battery Discharge Interlock (BDI) may have fired. Check the battery condition. Make sure the battery size is consistent with that expected by the controller. Adjust the controller to the proper battery size if necessary.
Truck shuts down when subjected to a heavy load.	You may have exceeded the battery current limit for this controller. Lighten the load or circumstances causing the heavy draw.

Truck loses top end (cuts back) after extended use.	Battery Discharge Interlock (BDI) may have fired because you are using all the usable capacity of your battery. Check the battery condition. You may be exceeding the average current limit. Use the **ProBit** to check the limits section. You may have passed the temperature limit by exceeding the safe operating temperature of the controller. Use the **ProBit** to check the limits section.[3]
The truck occasionally stops for no reason at all and must be taken through the proper startup sequence before it will move again.	You may have a faulty SRO switch. Check and replace if necessary.

Table 7: Problem Identification

A. PERIODIC MAINTENANCE

1. Overview

Periodic maintenance (sometimes referred to as preventative maintenance) is a system for reducing repairs by regularly checking the condition of all parts. The TSE1000/TSE550/TSE600 controller provides a number of features that improve periodic maintenance.

Among the TSE1000/TSE550/TSE600 features for periodic maintenance are a series of internal clocks. One of these clocks is the PM time. This clock records the amount of time that the controller has been on since the clock was cleared during the last maintenance check. This clock can be used to simply record the amount of time the truck has been running since the last periodic maintenance period, or it can be used as one qualifiers to decide when periodic maintenance should be performed (i.e. periodic maintenance is performed every four weeks or whenever the PM timer reaches 200 hours.).

2. Procedure

Some of the other tools that may be used during periodic maintenance are described below:

a) Checking Errors

The TSE1000/TSE550/TSE600 saves a record of the errors that occur while they are running. These errors may give an early indication of potential problems on a truck. The **ProBit** provides identifies these errors so they can be checked by maintenance personnel.

b) Clearing Errors

After reading the errors and dealing with any potential trouble spots they identify, service personnel should clear the errors from the controller's memory. If errors are not cleared they will continue to be reported every time the error codes are checked. You can delete errors with the **ProBit**.

c) Resetting Timers

As part of periodic maintenance, service personnel should reset the various clocks in the TSE1000/TSE550/TSE600 (see table 5: *Data Logging* on p. 18 for a list of these clocks). If this information is being kept for use in a fleet management program then it should be recorded before the clocks are reset. The timer information can also be used to determine the

[3]NOTE: If you regularly exceed the average current limit or temperature limit then either the controller or the truck may be undersized for the task it is being asked to perform.

level of use the truck has received and therefore the thoroughness of the periodic maintenance/inspection it will receive. The timers can be reset using the 'Clocks' section of the **ProBit**.

B. WHAT TO DO WHEN THE TRUCK CUTS OUT OR CUTS BACK

Under some circumstances the truck will cut back from normal output to protect the system and the operator. The various cutbacks, their symptoms, causes, and corrective measures are described below. The cutbacks and errors sections of the **ProBit** may be used to determine the cause of a cutback.

1. Speed Limit/Cutback Switches

If any of the speed limit/cutback switches are closed the controller will cutback to the preprogrammed level for that switch. If none of these switches are connected this form of cutback will not occur. (See section *L. Speed Limit Switches* on p. 13 for more information.)

2. Battery Discharge Interlock (BDI)

The TSE1000/TSE550/TSE600 keeps track of the battery capacity of the truck. If the capacity drops to 0% or less usable capacity then the controller will cut back to limp speed after a five minute grace period. The lift pump will also cut out under these conditions. Turning the key off and on again will reset this timer allowing an additional five minutes of operation for urgent tasks.

3. Over Current Limits

The controller will also cutback if any of the current limits are exceeded. The amount of the cutback and the length of time it lasts depends on the severity of the over current condition. The effects of each of the current limit is described below.

a) Peak Motor Current Limit

Whenever the peak motor current limit is exceeded the controller will cut the motor output back to the level you have set. It cuts back the motor output quickly in the face of excessive demands and quickly restores the output when the excessive load is removed.

b) Average Motor Current Limit

The average motor current protection limits the continuous average motor output to the preset level. It responds slowly to changes (allowing peak demands) and cuts back only when the average current limit has been exceeded for several minutes. Likewise once the controller has cut back the motor output it waits until the output remains below the average current limit for several minutes before returning to higher outputs.

c) Battery Current Limit

The battery current limit protects the controller against excessive draws from the battery. If this limit is exceeded the controller will record the appropriate error code. This limit should only be exceeded under very heavy loads, such as a short across the motor. If a limit of this sort occurs the controller will remain shut down until the direction selector is returned to neutral and the driver goes through the safe startup sequence. If the load that caused the cutback is not removed the controller will cutback again. Repeated attempts to start up the controller without clearing this load may damage the controller.

4. Over Temperature Limit

The controller can be damaged by operating it at excessive temperatures. For this reason if the controller detects an high temperature condition it cuts back the output accordingly. The TSE1000/TSE550/TSE600 will cut output to zero if its temperature exceeds 95ºC. If an over-temperature condition occurs the only way to clear it is to allow the controller to

cool down. The efficient design of the TSE1000/TSE550/TSE600 should prevent this condition from occurring under normal use.

5. Direction Contactor Failure

If either contactor fails to pull in or drop the controller will return to zero. The controller records an error code for contactor failures. The controller will not start again until the contactor is fixed and the controller is turned off and back on again. (f contactor errors occur for no apparent reason the contactor change time may be set too low.)

The controller will also stop if it detects a shorted coil in one of the contactors. The only way to get the controller to start in this case is to turn off the truck, fix the coil, and then turn the truck back on again.

VI. APPENDICES

A. NAVITAS TECHNOLOGIES TSE1000/TSE550/TSE600 WARRANTY

You have received with your TSE1000 or TSE550 motor controller a copy of the full warranty, complete with legalese. This explanation does not in any way replace the warranty, but, rather, is our attempt to explain it the way we would if we did not have a lawyer.

THE PURPOSE OF THE NAVITAS TECHNOLOGIES WARRANTY

The purpose of our warranty is to allow us to make sure the item you receive lives up to our standards. We want you to receive the best we have to offer and, if perchance you don't, we want to have an opportunity to make things right.

But even though we at Navitas Technologies are of above-average decency, we are not looking for chances to make up for other people's mistakes. And so, as you may have guessed, our warranty does not apply when damage results from failure to follow the instructions in this manual or from flagrant disregard for the laws of nature (gravity, inertia, lift trucks don't float, etc.).

TERMS OF THE TSE1000/TSE550/TSE600 WARRANTY

We promise to replace or repair any defective item within twelve (12) months or 2000 hours of normal operation (whichever comes first). We figured that should give you enough time to find even the smallest defect. If something should go wrong, contact your area NAVITAS dealer and you will receive a replacement controller at no cost.

B. THE PROBIT

The **ProBit** is designed to help you customize other NAVITAS products. The ProBit will recognize the controller and present the appropriate customization options. Full details on how to set specific parameters are found in the **ProBit** manual. The parameters themselves are explained in this manual.

To use the pendant:

1. Plug the **ProBit** connector into the top left connector on the controller. The connector goes in easily in one position, but it can be forced in incorrectly. Please be careful to observe the correct connector orientation.
2. Turn on the key switch. The **ProBit** will now show the "welcome" menu. You can now follow the instructions in the **ProBit** manual to adjust controller parameters.

C. TECHNICAL SPECIFICATIONS

1. Power Handling

The TSE1000/TSE550 controller is designed to operate with batteries with a nominal voltage of 24 V to 48 V. The TSE600 is designed to operate with a nominal battery voltage of 24v to 48v. The TSE1000 is rated for 325A continuous (average) current with 1000 A peak current. The TSE550 is rated for 175A continuous (average) current with 550 A peak current. The TSE600 is rated for a 260A continuous (average) current with a 600A peak current. See also *Controller Limits*; p. 16.

2. Input Protection

All the inputs on the TSE1000/TSE550/TSE600 **except** for the main power connections and the NAVITAS bus are protected against accidental mis-wiring.

3. Contactor Drive Specifications

The controllers' built-in contactor drivers will supply a drive voltage from 12V to B+ and a drive current of up to 2A. Note that the controller detects a fault condition if the contactor current is greater than 2 A.

D. GLOSSARY

Current Multiplication

The increase in current seen in a motor when driven at low chopping levels. The average voltage that the motor is driven with is lower than the battery voltage supplied to the controller. Since the controller is highly efficient, the power supplied to the motor must equal the power supplied to the controller. This can only be the case if the current in the motor rises by the same factor that the average voltage to the motor dropped.

Cutback

A condition in which the controller's normal operating output is reduced or limited below its programmed maximum.

Default

A setting that is programmed into the controller when it leaves the factory. These preset values should work for most trucks, but can be adjusted for a more exact match with the vehicle. The controller will use the default level unless another level is programmed into it.

Operating Error

An operating error is a mistake made by the driver. The most common such mistake is the failure to use safe sequencing (i.e. get into proper operating position, choose a direction, and then press the accelerator).

Parameter

An operating level (or value) that the controller uses to regulate one of its functions. I.e. the setting for maximum speed, or the setting for acceleration.

Plug Braking

A method of electrically braking a series motor. Supply a small drive voltage that would drive the motor in the opposite direction to its current direction of rotation provides a field that brakes the motor. This method of braking generates high motor currents that are dissipated in the motor and in plug braking diodes placed in the controller for this purpose.

RTN

Return to Neutral. An internal state of the controller. In the RTN the operator must go through the safe startup sequence before the controller will operate. Generated in response to a number of events including SRO and battery current limit.

Safe Sequencing.

Safe sequencing refers to the order in which the driver must operate the truck's controls. The order is as follows:

1) satisfy the SRO (sit on the seat of a rider, stand on the floor panel of a standup, or lower the operating arm of a walkie)

2) select a direction

3) press the accelerator.

The controller will not operate the truck if these steps are taken out of order.

SRO

Static Return to Off. A safety feature cotrolled by the circuitry of the truck. Most trucks contain a switch (or series of switches) designed to ensure that the operator is in control of the vehicle. As long as the switches are closed the controller will function normally. If one of the switches opens the controller should shut down since the operator may no longer be in safe control of the vehicle. The most common SRO switches are the seat switch in a sit down truck, and the foot pedal in a standup.

System Error.

This term refers to problems in the operation of the truck and its parts. For example, a welded contactor, overheating, low battery voltage. When a system error occurs, the controller shuts off power to the drive motor.

VII. INDEX

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