DRAFT MANUAL

TURBO COMMANDER

INSTRUCTION MANUAL

WARNING: This product enables you to control and enhance the performance of your turbocharged vehicle. The Turbo Commander is designed to be used by knowledgeable professionals in the area of vehicle turbocharging and engine dynamics. Improper use of the variable turbocharger control features may result in turbocharger failure and irrecoverable engine damage.

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Introduction

The Turbo Commander is a cutting edge turbocharger telemetry package and Variable Geometry Turbocharger controller. Variable Geometry Turbochargers can change geometric shape in response to changing engine conditions. Depending on the manufacturer of the turbo, Variable Geometry can mean changes in turbine exhaust gas feed, nozzle geometry, gas vectoring, or volute geometry. By monitoring sensor feedback from the turbocharger, the Turbo Commander can control an actuator attached to the VGT mechanism in the turbo.

Proper control of the variable geometry turbine is critical for the efficient use of fuel and low engine RPM torque production. Retrofitting variable geometry turbochargers onto vehicles not originally equipped with this technology is made possible with the Turbo Commander. This is ideal for performance enthusiasts and fleet vehicles trying to save fuel costs while enhancing engine performance compared to conventional turbochargers.

The Turbo Commander is turbocharger platform agnostic and can communicate with or directly actuate a variety of actuators. Compatible actuators include CAN bus actuators such as Holset and Delphi, stepper motor position control, and solenoid actuation.

The Turbo Commander works by monitoring the state of different turbocharger parameters including:

- Charge pressure
- Charge temperature
- Exhaust pressure
- Exhaust temperature
- Intake air temperature
- Barometric pressure
- Turbine RPM
- Throttle position
- Mass air flow
- Exhaust break user input (switch)

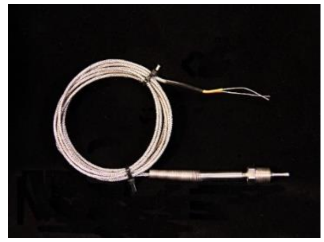
All or a subset of these parameters may be used to set operating conditions of the turbocharger. A control loop adjusts the turbo to the target state based on user defined limits and targets for these parameters. The user defined limits are set up with convenient PC software that connects to the Turbo Commander via USB.

Using the Turbo Commander app for Android devices, the user is able to view feedback from the engine over Bluetooth. This is convenient to replace in-cab gauge pods. The user can also stream and record live time-synchronous data via USB. The ability to stream and record high data rates in the field makes the Turbo Commander an extremely powerful diagnostic tool for engine engineers and laboratory work.

The Turbo Commander is a one of a kind, multi-function tool for turbocharger feedback and control. Not only does it provide all of this in one box, it can also be installed on any engine and set up to work with any variable geometry turbocharger.

What's included with the Turbo Commander kit?












- The Turbo Commander unit.
- Exposed tip Air Charge Temperature (ACT) thermocouple.
- Shielded tip Exhaust Gas Temperature (EGT) thermocouple.
- M12 PUR over molded stepper connection cable.
- Sensor terminal connector.
- Main terminal connector.
- 15' Gold plated USB cable assembly.
- 5' Trelleborg medical/aerospace grade braided silicone hose. (Platinum cured / 500°F tolerant)
- Miniature inline exhaust pressure particulate filter.
- Inline blade type fuse holder.
- T-Tap connectors for easy vehicle wiring integration.
- Turbo Commander Windows software (For download visit www.suprocktech.com)
- Turbo Commander Android App (For download visit Google Play Store)
- Bosch style relay and socket.

Manufacturers of Variable Geometry Turbochargers

There are many different manufacturers of variable geometry turbochargers. The Turbo Commander can be used to actuate any turbo with the appropriate mechanical actuator and power source. It is important to choose the correct turbo for the engine application by comparing specifications and designs between manufacturers.

- Blaylock Turbochargers- Swtichblade
- HOLSET- HE351VE, etc.
- Honeywell- VNT

Installation of the Turbo Commander

Preparation

Considerations:

- Disconnect the battery in your vehicle before modifying the electrical system.
- Prepare a circuit with chassis ground (GND) and a positive (+) connection to your 12V or 24V vehicle electrical system.
- The circuit should be fused with a 10A inline fuse on the (+) circuit.
- Choose a mounting location for the Turbo Commander. Engine bay locations are acceptable as long as the device is not exposed to direct heat exceeding 158°F/70°C. Water/salt spray must be avoided to prolong the life of the connectors and device.
    - Preferred mounting locations include locations inside the vehicle cabin accessible to firewall wire grommets for the vehicle wiring harness. Existing wire grommets ease the connection to sensors and actuators that are located in the engine compartment.
- Plan your installation approach, including what type of mechanical actuator will work best with your turbo and power source options (e.g. air, electrical, hydraulic, etc.)

Tools and materials:

- Wire stripper.
- Hookup wire. 16 AWG stranded is recommended. Red and black colors are preferred for recognition.
- Heat shrink tubing.
- Small standard screwdriver to tighten terminal connectors.
- Inline fuse holder and fuse (if not connecting to a fused circuit). 10A blade type fuses are recommended.
- High temperature silicone hose for pressure sensor connections.
    - Recommended Trelleborg medical grade silicone tubing: McMaster Carr PN 5157K41. This tubing product can survive extreme temperatures, pressures, and strain. It is suggested since it has demonstrated high performance connecting to exhaust manifold pressure bungs without cracking or collapsing.

Once all preparations have been made, the next step is to prepare the connectors with the appropriate inputs and outputs you wish to use with the Turbo Commander.

Connector Pinouts

The Turbo Commander has two user-wired connectors that attach to the unit for input and output signals, power, actuator control.

FIGURE 1 MAIN SENSOR CONNECTOR

FIGURE 2 SENSOR CONNECTOR

FIGURE 3 M 12 STEPPER CONNECTOR

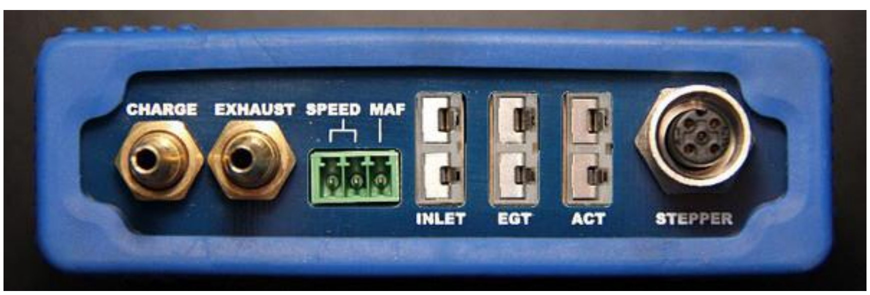


FIGURE 4 SENSOR & STEPPER CONNECTIONS

FIGURE 5 USB, CAN, SENSOR, AND POWER CONNECTIONS

Main Connector

The first connector is a 12 position terminal connector containing the main device power connections to (+) and chassis ground along with several optional inputs and outputs.

Power connection

The power connection will operate from 10V to 30V DC suitable for all 12 and 24V vehicle power systems.

Analog Inputs

This connector contains inputs for analog throttle position voltage and auxiliary (spare input) voltage. The throttle position input is a single wire connection made to the 0-5V TPS sensor signal found on many vehicles. The 0-5V auxiliary input can be used to read any vehicle sensor that has analog voltage output in this range. In one example, an alternate sensor could be a 0-5V MAF used on some vehicles that do not use a frequency open collector MAF.

Actuator Connections

SOLENOID

The solenoid actuator connection has two terminals intended to energize the coil of a solenoid valve. Most solenoids have an isolated coil (two leads) and operate regardless of connection polarity. The -SOLENOID terminal is internally switched to ground when the solenoid is actuated by the Turbo Commander. The solenoid connection supports up to 1.70A of current through an inductive or resistive load.

CAN BUS ACTUATOR

The CAN bus actuator connects to a Delphi, Holset, or other CAN compatible actuators found on many commercial turbochargers. The actuator is powered by the CAN ACTUATOR POWER terminal and the actuator must be connected to ground at the CAN ACTUATOR GROUND terminal. When using a CAN actuator, make sure the power supply connected to the Turbo Commander can source up to 10A of current.

STEPPER ACTUATOR

The stepper motor connector is an industrial M12 style connector. This connector differs from the other terminal block connectors on the Turbo Commander because stepper motors are typically sold with short wire pigtails and the stepper drive current can be relatively high. The M12 connection ensures current handling and wire routing for a stepper is reliable. A discussion of wiring an M12 cordset to a stepper motor is presented in the Applications Examples/Wiring Actuators section of this manual. The stepper controller inside the Turbo Commander supports up to 3A of output current into the phases of the stepper motor.

Sensor Connector

The second connector is a 3 position input terminal connector which allows connection to frequency based sensors such as turbocharger speed sensors and common mass airflow sensors.

Mass airflow sensor connection

The Turbo Commander is designed to read frequency from open collector type mass airflow (MAF) sensor units. Open collector type MAF sensors have a pin that is switched internally to ground at a frequency related to the airflow through the device. Some popular MAF sensors are made by GM/Delphi and work on the theory of a hot wire anemometer.

The Turbo Commander will read and log MAF frequency through a single wire connected to this terminal. There is no need to connect the MAF ground since the signal is sufficiently referenced to vehicle chassis ground, and open collector frequency signals are highly noise immune.

Turbocharger rotor speed sensor connection

The Turbo Commander can read a variable reluctance speed sensor. The type of sensor that should be used with the Turbo Commander is a passive VR sensor with two lead wires. Appropriate part numbers are available from Honeywell, for **example PN 3030S30.** For in-depth information please refer to our application discussion on Turbo Speed Sensor Installation in this manual.

Input and Internal Sensor Specifications

Internal Sensors

Pressure

There are two pressure sensors internal to the Turbo Commander that are intended to measure charge pressure and exhaust pressure. These sensors are exposed through two brass through-panel connectors and labeled according to their function. **When using an exhaust manifold pressure connection, be sure to elevate the Turbo Commander above the inlet to avoid soot deposits brought into the sensor by condensation. Also, use the inline filter provided with the Turbo Commander kit to avoid soot contamination.**

A third pressure sensor measures barometric pressure internal to the Turbo Commander. This sensor is inside the case and does not require an external connection.

PRESSURE SENSOR INPUT SPECIFICATIONS, CHARGE PRESSURE / EXHAUST PRESSURE

- Measurement range 0-100PSI gauge pressure.
- Resolution ±0.03% of full scale.
- Accuracy tolerance better than ±0.25% full scale.
- 100% tolerant of liquid condensing or direct liquid exposure.
- 1ksps sampling rate.
- 16 bit ADC resolution.

BAROMETRIC PRESSURE SENSOR SPECIFICATIONS

- 7.25-16.6 PSI Absolute.
- Can resolve changes in altitude of 16cm/2.5”
- Accuracy tolerance better than ±0.04% full scale.
- Minimum of 1sps sampling rate.
- 20 bit ADC resolution.

Temperature

The Turbo Commander measures its internal temperature in order to cold junction compensate the external thermocouples. This internal temperature sensor measures temperature on the circuit board within 1%.

External Sensor Inputs

THERMOCOUPLE SENSORS

The Turbo Commander can accept 3 thermocouple sensors. These inputs are intended for measuring type K thermocouple sensors for charge temperature, exhaust temperature, and air intake temperature. The labels on the Turbo Commander case reflect this typical application. Other uses of these thermocouple sensors beyond the typical configuration are feasible and are discussed in the application examples.

- Type K thermocouples only.
- Sampling interval 3ms for charge temperature.
- Sampling interval 3ms for exhaust temperature.
- Sampling interval 9ms for intake air temperature.

Each thermocouple input checks for open circuit (broken or disconnected sensor) every 20mS.

ANALOG INPUTS

There are two analog inputs on the main connector of the Turbo Commander. One of these inputs is intended for attachment to a Throttle Position Sensor (TPS). The input has a high impedance so it does not interfere with the sensor reading which may be shared with the vehicle Engine Control Unit. The second analog input pin is available for user applications, and can be used with any 0-5V sensor. These input pins have the following specifications:

- 0-5V.
- High impedance input.
- 10 bit resolution.

TURBO SPEED SENSOR CONNECTOR

The Turbo Commander has a connection for a variable reluctance (VR) sensor. This connector accepts a frequency input generated by a passive VR sensor. This input is insensitive to the magnitude of the VR signal and measures only the frequency of the input signal. Inputs over the voltage range will be clipped however frequency will still be measured.

- Minimum frequency reading is software configurable depending on user setup. Typical low RPM reading is 3.663 kRPM (62Hz).
  - Also dependent on physical VR sensor installation configuration, refer to application note. Minimum pickup speed may be related to the installation configuration of the sensor.
- Maximum frequency reading of 200kRPM.

MASS AIR FLOW SENSOR

- Open collector type sensors can be connected.
  - Delphi and GM MAF sensors are compatible.

- Pin impedance of 10kΩ through a pull up to 3.3V.
- Measures switched frequency of the sensor.
- Measures frequencies above 488Hz.

EXHAUST BRAKE SWITCH

The exhaust brake inputs connect to an external switch (provided by the installer) to toggle exhaust brake functionality on the turbo controller. When the exhaust brake pins are connected to each other through a switch circuit, the Turbo Commander will enter exhaust brake mode if the configuration permits the exhaust brake to become active.

Recommended External Sensors

VARIABLE RELUCTANCE SENSOR

Two-wire Variable Reluctance sensors are recommended for turbo speed sensing with the Turbo Commander. Honeywell manufactures a variety of these sensors. One recommended part is a ¼"-20 thread sensor PN 3030S30. However, other sensors work such as the 2 wire VR speed sensors that come mounted in many Holset CHRAs.

Some turbochargers come equipped with VR sensors. Some models of the HE351VE are equipped with a VR sensor from the factory. These OEM VR sensors are suitable candidates for the Turbo Commander. The image below shows a VR sensor attached to a HOLSET CHRA.

THERMOCOUPLE SENSORS

Type K thermocouple sensors are supported by the Turbo Commander. The connector style is an industrial 2-prong thermocouple plug. We recommend using high grade USA made thermocouples such as those provided by OMEGA Engineering or similar distributors. Suprock Technologies also sells external armored thermocouples along with the Turbo Commander as well as replacement thermocouples.

In the exhaust gas temperature (EGT) application, thermocouple fouling is a primary consideration. Use a shielded thermocouple only for exhaust measurement since the carbon deposits on the thermocouple are conductive. Moreover, ionized combustion gasses can also be conductive.

Configuration Software for Windows

The Turbo Commander comes with a software package capable of configuring control settings and capturing live stream data to your computer. The software is compatible with versions newer than Windows 7 on both 32 and 64 bit computers. The Microsoft Surface is a recommended computer for laboratory and road use because it has a reliable touch screen interface, has a native USB port, and is easily mounted in the vehicle.

Helpful Terminology and Definitions

- **Cruise mode**- An option available in the actuator control configuration which disengages or sets the actuator to the open position based on the voltage input to the Throttle Position connection.
    - *How it works:* Cruise mode is advantageous during constant low engine load conditions when it is desirable to have minimum exhaust back pressure for maximal fuel economy. Cruise mode can open the variable geometry turbine to reduce the back pressure on the exhaust and allow the engine to operate more efficiently.
        - An example is highway operation, when the throttle position is low and the variable geometry is not needed to assist with increasing charge pressure.
        - Freight diesels pay attention! This is where you will pick up highway mileage and lower EGTs with your variable geometry setup. Since the Turbo Commander is not attempting to apply back pressure for EGR during highway use, this setting does what is thermodynamically best for the engine efficiency- Eliminating back pressure at times when the variable has no performance benefit.

- **Exhaust brake**- A setting that puts the turbocharger into the user defined (or predefined) exhaust brake position based on completing an external circuit (switch). This is typically applicable to larger diesel vehicles although it can be implemented on smaller engines. This function can only apply an exhaust brake on turbochargers designed to have an exhaust brake position. External exhaust brakes are not driven directly by the Turbo Commander since they do not require complex control (e.g. switch based or pedal position controlled).

- **Control loop-** In the Turbo Commander, this refers to the proportional control of the actuators between the Start and Target set points. In the case of the solenoid actuator, this is a binary control instead of proportional.

    - The Turbo Commander has options to control the actuators based on measured shaft speed or charge pressure.

- **Target**- The ultimate goal of the control loop. Once the target has been reached, the turbocharger is fully open and in a maximum flow condition.
    - *How it works*: Target is used to define either a shaft speed or charge pressure at which the variable turbocharger mechanism should be fully open for maximum exhaust flow.
        - Example: Based on a compressor map, an efficient shaft speed at full boost is 100kRPM. The user may set the target shaft speed to 100kRPM so that the variable turbo is fully open when the target is achieved.
        - In theory, there is no additional performance advantage from a variable geometry mechanism after the rotor inertia is at speed or the desired charge pressure is achieved. Once the turbo is at speed, the variable turbo should be in a position to minimize exhaust back pressure and EGTs.

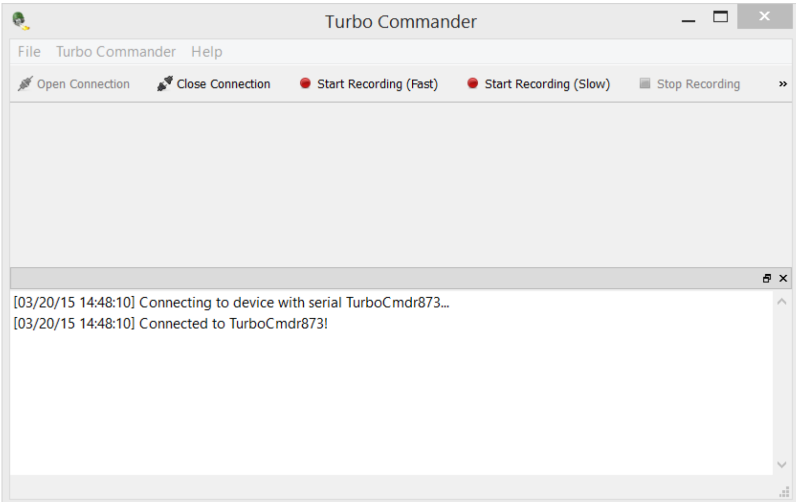
- **Start**- The speed at which the control loop begins to start changing the variable geometry from the maximum exhaust velocity configuration towards the open maximum exhaust flow condition. In other words, when the variable geometry starts to open up in response to the increased shaft speed or charge pressure being observed.
    - *How it works*: The low end of a compressor map shows a speed defining the lower bound on the efficient compressor region. This shaft speed is a good candidate for the Start RPM. Likewise, the pressure ratio on the low side of the compressor map will define a good place to start when using charge pressure control.
- **Closed-** The position of the variable mechanism producing the maximum exhaust gas velocity. This is the setting that "spools" the turbo the fastest. This position will create higher exhaust gas back pressure, with the exception of the Exhaust Brake position (if the turbo is capable of applying an exhaust brake).
- **Open-** The position of the variable mechanism permitting the maximum exhaust gas flow. This is the setting that is desirable once the turbo has reached the target operating conditions. The open position produces the lowest exhaust gas back pressure for minimizing EGT and maximizing engine power.

Installing the Turbo Commander PC Software

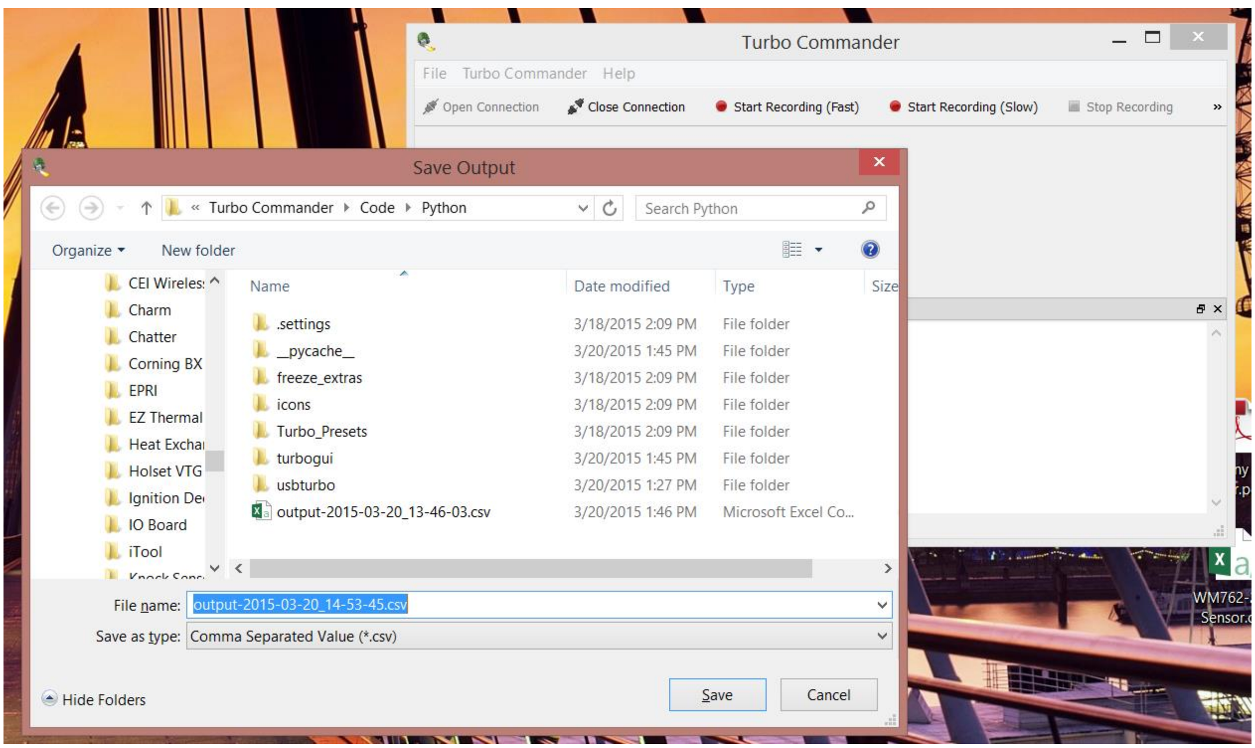
Installing the Turbo Commander PC software is accomplished by downloading the installer application from www.suprocktech.com and following the typical installation procedure.

Getting Started / Basic Data Acquisition

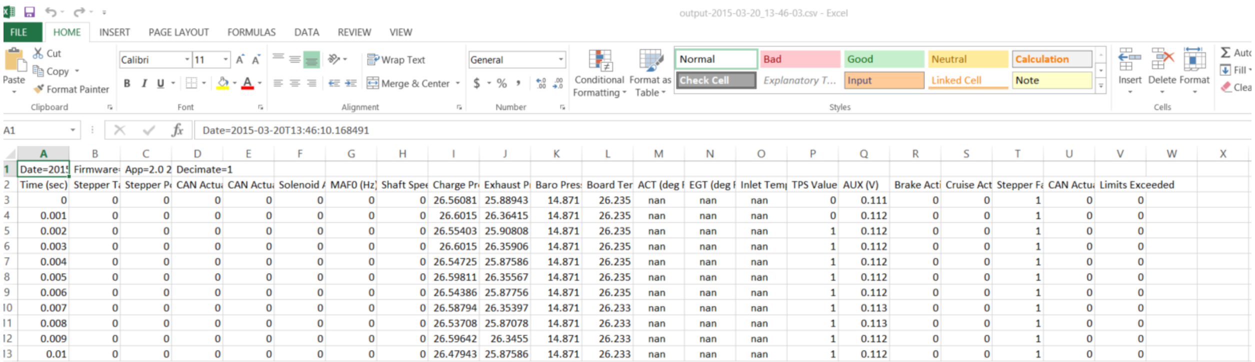
Once the software has been installed, provide power to the Turbo Commander and connect the USB port to your PC. Wait for Windows to finish installing the driver. Open the Turbo Commander software and click Open Connection. The Turbo Commander will connect to the PC application and report serial number and connection status in the notification prompt. This is the application main menu. There are buttons for recording sensor data either fast (1ksps) or slow (10sps). These buttons make logging easy when you're on the road or conducting live tests.



If you choose to record data from the Turbo Commander, you will be asked where to save the data. The format is comma separated variable, csv. This format can be easily viewed and manipulated in Microsoft Excel, Google Docs, or advanced programs like MATLAB.



If you choose to analyze the data, it can be opened in Excel. Each column header clearly identifies each data source for easy analysis. Some users will prefer importing this data into MATLAB or other analysis packages.

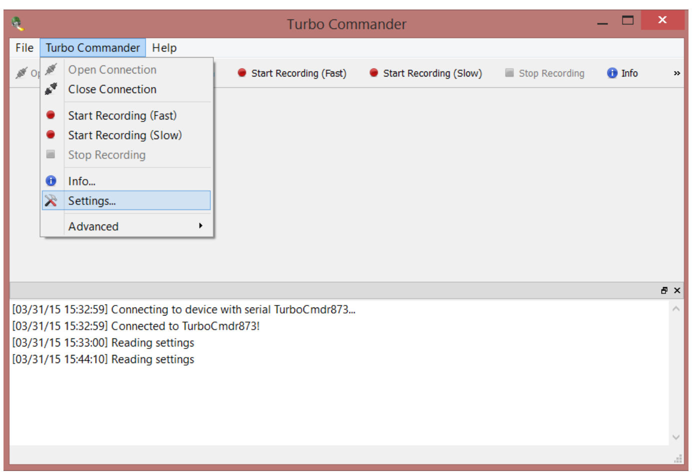


The Turbo Commander captures a wealth of data about the state of the turbo and the control loop. At first, this amount of data may seem overwealming. However it is easily divided into categories of internal sensors, external sensors, control system status, and the actuator(s) feedback. Tips on analyzing this data are beyond the scope of the hardware manual, but will be made available as application notes.

Settings

Control settings

To set up or modify settings on the Turbo Commander, enter the Settings menu. This will bring up the settings tabs, discussed in detail below.



General settings

The general settings tab contains a checkbox to enable the actuator control loop on startup. This is typically selected for normal operation so that the Turbo Commander controls the actuator according to the sensor inputs. Deselecting this checkbox will disable the control loop by default and the turbo commander will not control the actuators.

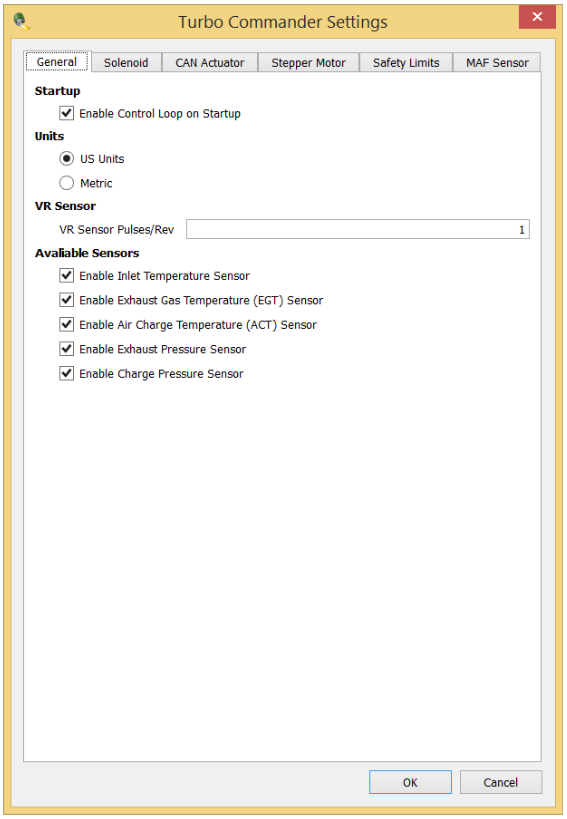
The units preference is available on this settings tab. If you're not an American, you may check this box.

The VR sensor Pulses/rev is based on the configuration of the VR sensor if one is used as a sensor input. In the section of this manual "Installing a variable reluctance speed sensor" a discussion of various techniques is presented, resulting in different values for pulses per revolution being detected by the VR sensor.

Available Sensors

The check boxes allow the installer to select which sensors are installed so the Turbo Commander can ignore sensors with no input or connection. This is important so that when safety limits are implemented that the readings from disconnected sensors do not result in a false error condition. This is also important for notifications in the Android app

The selections include pressure and temperature sensors. The Turbo Commander must be told to ignore inputs from these sensors if they are unused.

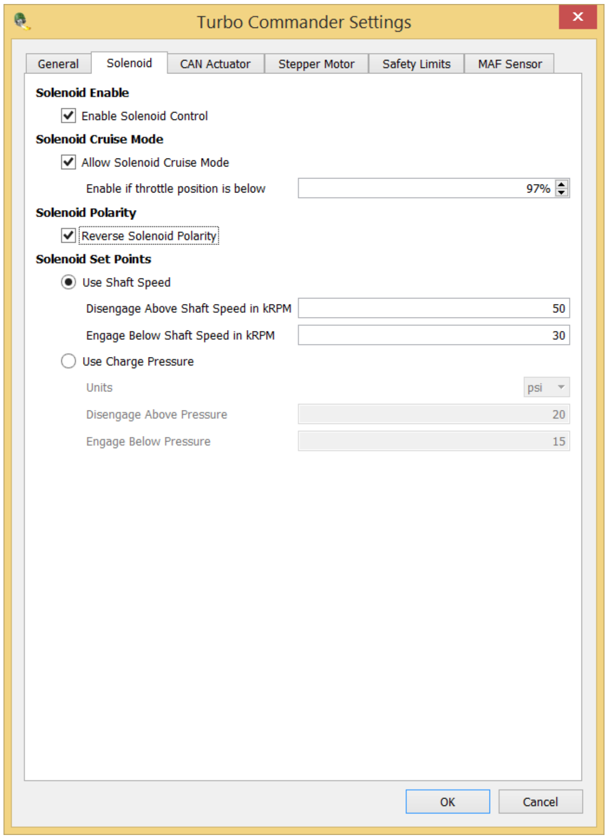


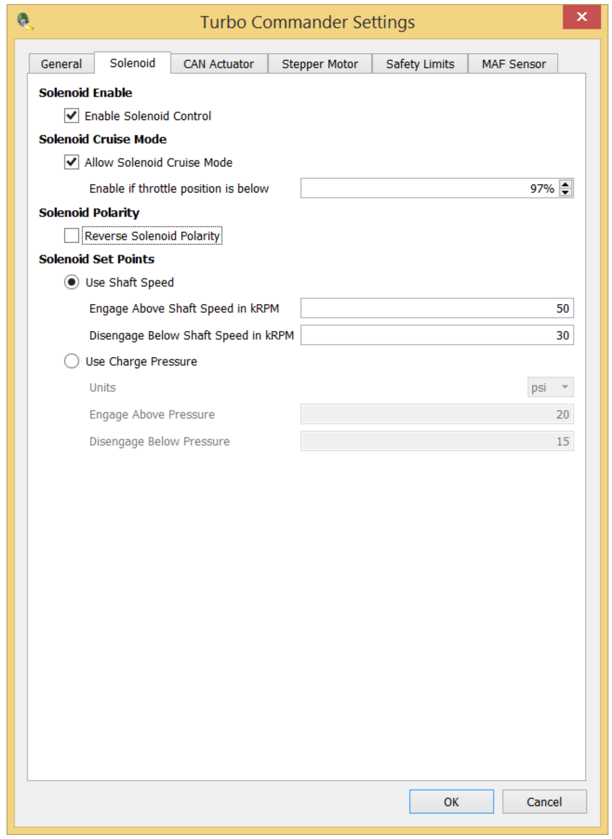
Solenoid

The solenoid can be configured to actuate independently based on the settings found in the Solenoid tab. The solenoid actuator has a cruise mode option which will disengage the solenoid (normally closed meaning a solenoid valve will shut) if the throttle position is below the given percentage of 5V.

The solenoid can be controlled either from charge pressure or from shaft speed. Although a solenoid is usually a binary device not requiring a proportional control, there are two set points for engaging and disengaging the solenoid so that the user may add hysteresis (a gap, or difference) between the values. The solenoid will be engaged or disengaged as it passes through these set points. Hysteresis will prevent rapid toggling of the solenoid when the sensor value is passing through the set point. This results in a more stable and repeatable control for applications such as opening and closing a valve.

There is an option in the settings to reverse the polarity of the solenoid so that the control loop can reverse the order of actuation. When controlling a solenoid valve, this is applied depending on the type of actuator being used and whether the actuator is normally closed or open.



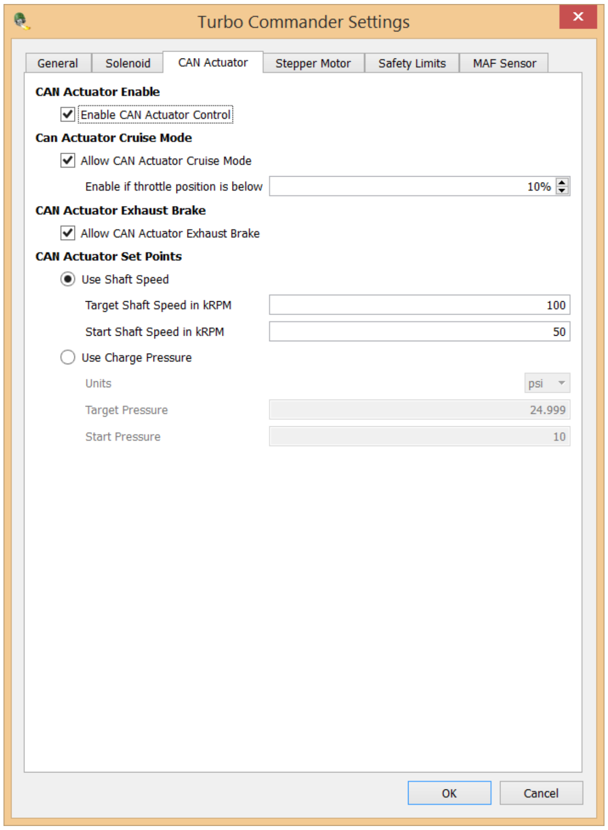


CAN Actuator

The CAN actuator can be configured to actuate independently based on the settings found in the CAN Actuator tab. The CAN actuator has a cruise mode option which will move the CAN actuator to the open housing position if the throttle position is below the given percentage of 5V.

The CAN actuator can be controlled either from charge pressure or from shaft speed. The actuator position varies proportionally from closed (maximum exhaust gas velocity) to open (maximum exhaust gas flow) between the control set points.

The exhaust brake option will enable the CAN actuator to enter the exhaust brake position based on switched input to the exhaust brake input terminal.



Stepper Motor

The stepper motor can be configured to actuate independently based on the settings found in the Stepper Motor tab. The stepper motor has a cruise mode option which will move the motor to the user defined open housing position if the throttle position is below the given percentage of 5V.

The stepper motor can be controlled either from charge pressure or from shaft speed. The stepper position varies proportionally from closed (maximum exhaust gas velocity) to open (maximum exhaust gas flow) between the control set points. The range of movement for the stepper motor is defined by the user.

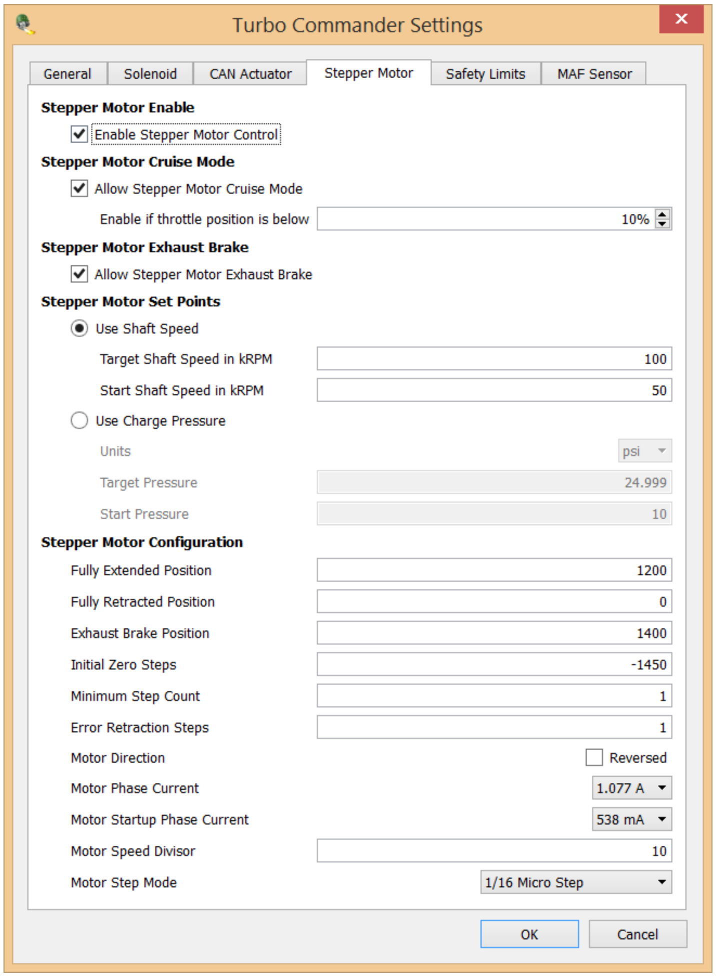
The exhaust brake option will enable the stepper motor to enter the user defined exhaust brake position based on switched input to the exhaust brake input terminal.

Stepper Motor Configuration

Unlike the other actuators, the stepper motor has configuration settings relating to the motor specifications and how the motor has been implemented as an actuator. Each configuration setting can be explained in terms of the physical actuation of a turbocharger. The installer must choose these positions. This setup process is explained with our application video on the subject of stepper motor configuration.

- Fully Extended Position- The position of the maximum velocity condition (i.e. vanes engaged, etc.) in terms of the number of steps to reach this position from the zero position.

- Fully Retracted Position- The position of the maximum flow condition (i.e. vanes disengaged or removed from flow) in terms of the number of steps to reach this position from the zero position.
- Exhaust Brake Position- The position that the stepper should reach to engage the turbocharger exhaust brake condition in terms of the number of steps to reach this position from the zero position.
- Initial Zero Steps- The number of steps that the stepper motor will attempt to take towards the fully retracted position when the Turbo Commander starts up. This number should be slightly higher than the maximum physical stroke of the motor.
- Minimum Step Count- The smallest number of steps that correspond to a control action. This defines how granular movements of the stepper motor will be.
- Error Retraction Steps- This is the number of steps the motor will retract towards the fully retracted position when a safety limit is violated. The motor will move repeatedly in this number of steps until the error condition is relieved or the motor reaches the fully retracted position.
- Motor Direction- This sets the polarity of the motor movement direction. This setting is helpful if the physical wiring of the stepper motor phases is reversed, the physical connection does not need to be altered.
- Motor Phase Current- The rated current of the stepper motor according to the stepper motor specification.
- Motor Startup Phase Current- The current applied to move the motor during initial zero steps. This allows a soft start and snubbing of the physical mechanism against the zero position without excessive motor force.
- Motor Speed Divisor- Larger numbers will cause slower rotation of the stepper motor.
- Motor Step Mode- A divisor on the full step degrees of the motor. For instance if 1/16 stepping is selected it will take 16 micro steps to complete a full step. This is for refined position control, since typical stepper motors have a coarse step resolution of 1.8 degrees. Be aware that changing this value will affect the value of Extended, Retracted, and Exhaust Brake positions since the number of steps taken to reach these positions will change.



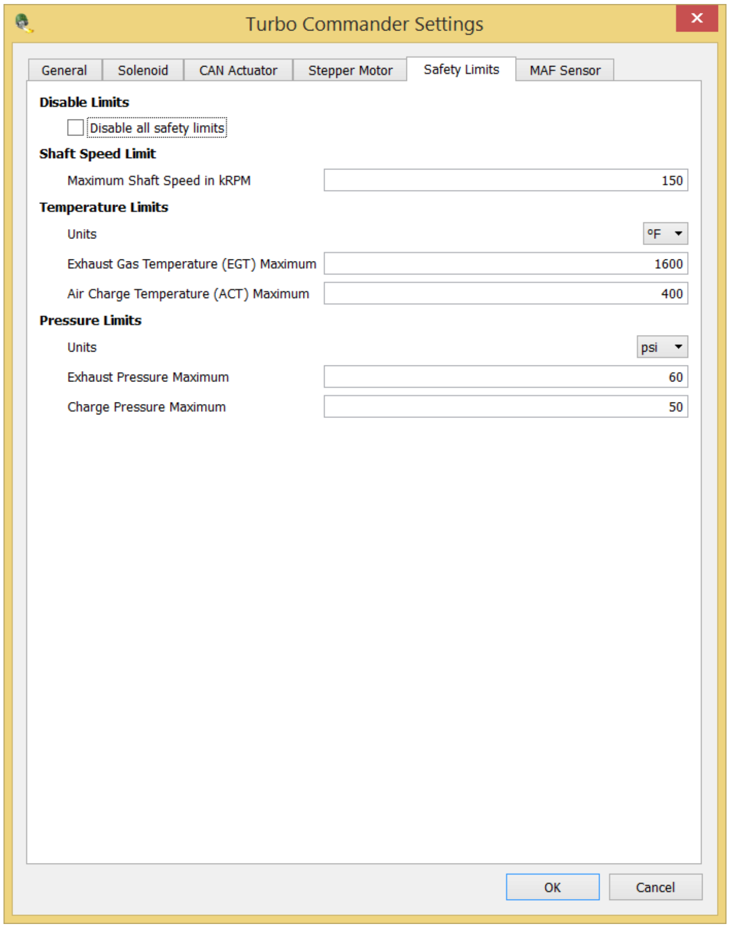
Safety limits

The safety limits available in the Turbo Commander are conditional control settings that help prevent dangerous operating conditions. These parameters may prevent mechanical damage to the turbocharger or engine. They can be applied as alternate control points that supersede the control loop under specific conditions that warrant opening of the variable geometry to reduce exhaust manifold pressure, exhaust gas temperature, or shaft speed.

If any one of the safety limits is exceeded, all attached actuators will respond.

- The stepper motor will home to the OPEN position as defined in the stepper motor settings.
- The Solenoid will become disengaged (normally closed for solenoid valves).
- The CAN actuator will move the VGT to the OPEN position for Holset turbos.

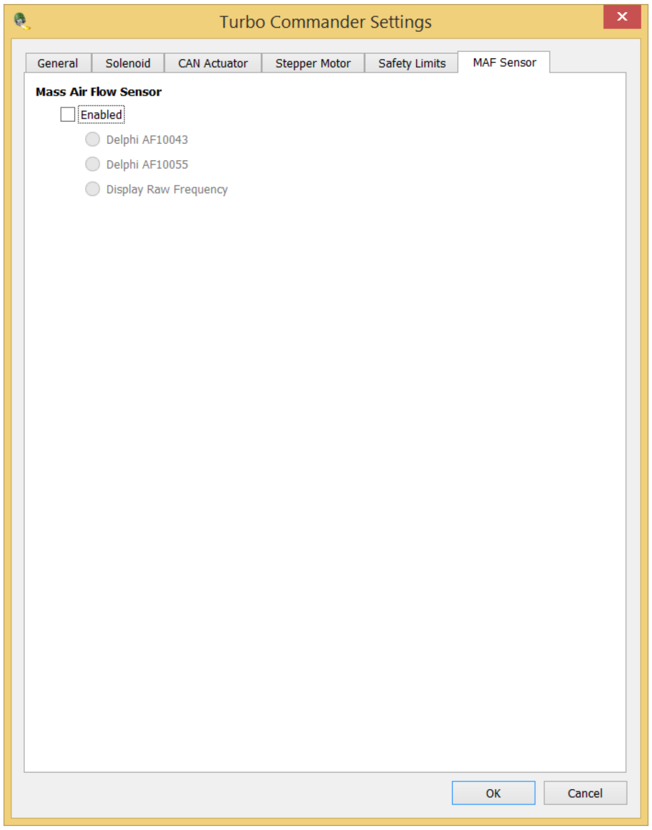
Checking the “Disable all safety limits” box will ignore the values set for all limits and the Turbo Commander behavior will adhere to the control loop.



Mass Air Flow Settings

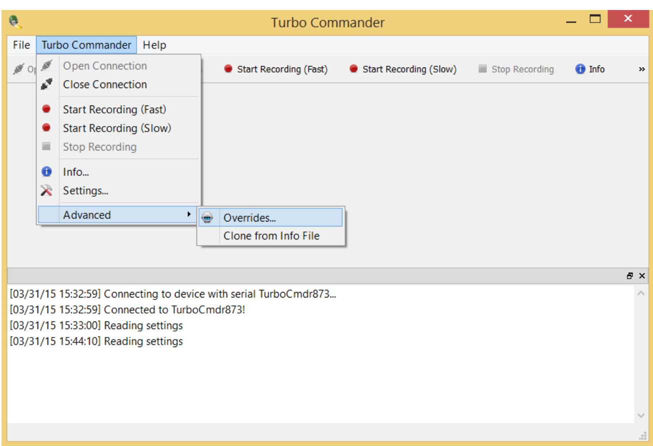
The mass air flow (MAF) settings allow the user to configure input from an open drain frequency signal MAF. There are some Delphi MAF units supported natively and this list may be expanded in the future. The list can be expanded in future upgrades of the PC software without requiring a re-flash of the Turbo Commander. Enabling the MAF will display the value on the MAF input in the Android app. No control loop functionality is based on the MAF, but it is useful for tuning and engineering purposes.

For 0-5V MAF sensors found on some vehicles, the analog auxiliary input (shown in Figure 1) can be used to record a signal. The MAF sensor settings do not apply to the auxiliary input.

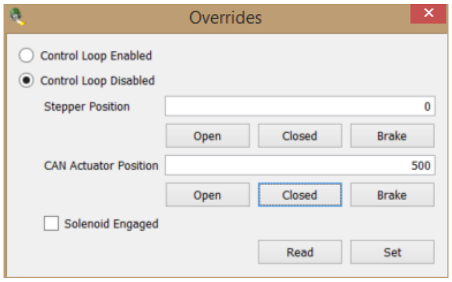


Manual Control Overrides / Actuator Testing

If you have attached actuators to the Turbo Commander, the Overrides functionality is a way to validate the physical wiring and set points of the actuator. It is also a way to set the turbocharger to a specific state and disable the control loop. In some cases, this can also be useful for dyno testing or exciting specific operating conditions. The overrides are acessed through the Turbo Commander menu under Advanced.



To administer an override condition, select “Control Loop Disabled”. This will stop the control loop from running and positions can then be entered manually. For convenience, there are buttons to set the turbocharger to the programmed Open, Closed, and Brake positions. These postitions will summon the user programmed values for the stepper actuator and the default positions for the Holset CAN actuator.



Android App

The Turbo Commander comes with a free app available for download on the Google Play Store. This App enables the Turbo Commander to display live sensor data on any Android device. The usefulness of this App is significant for field tuning and street use where the user may want to replace a number of traditional in-cab gauges with a mounted tablet or phone.

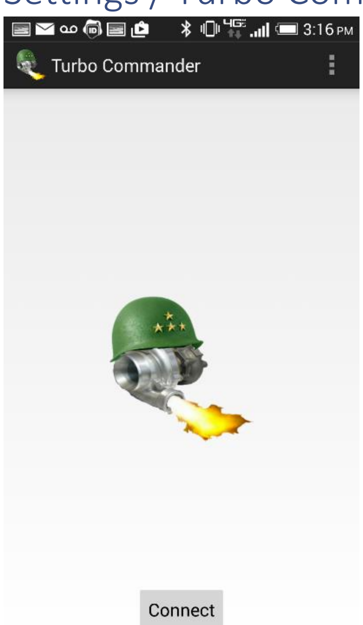
The App will be updated frequently through the Play Store to include new features for alerts, organization, and parameter display. This manual may lag describing new features being added to the app.

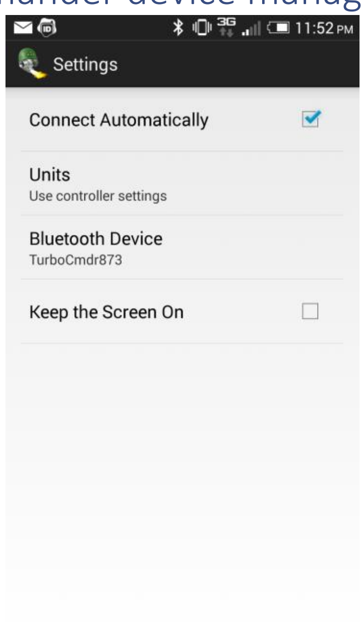
The Android App does not yet collect data streams over Bluetooth because of the high data rate required for sampling on all of the sensors. Refer to the Windows Software description for advanced data capture.

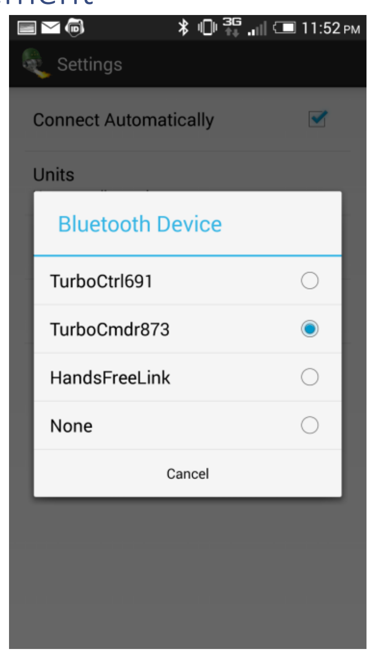
The Turbo Commander must be paired with the Android device in the device Settings/Bluetooth prior to using the Android App. Once the device is paired the Turbo Commander app will allow you to select connection and options.

For in-car display use, there is an option to keep the screen on so that the devie does not sleep.

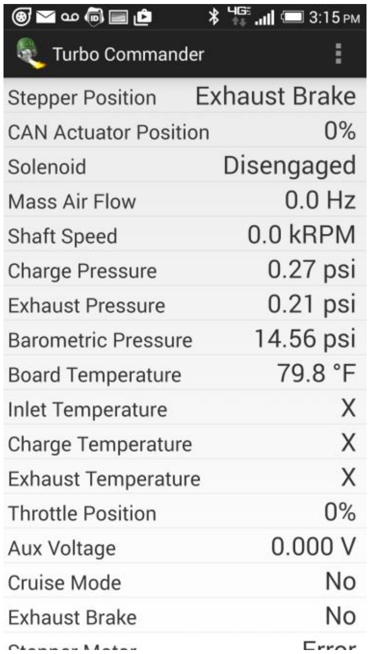
Settings / Turbo Commander device management

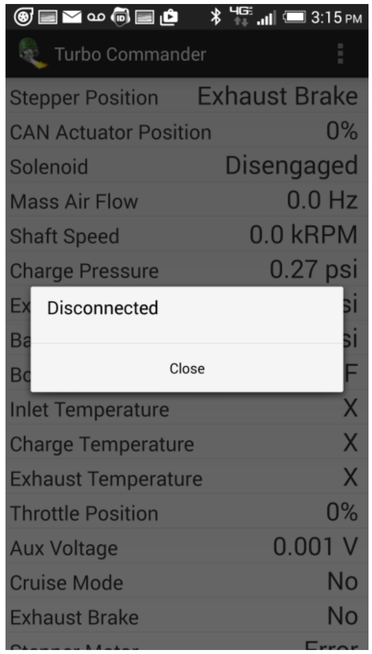






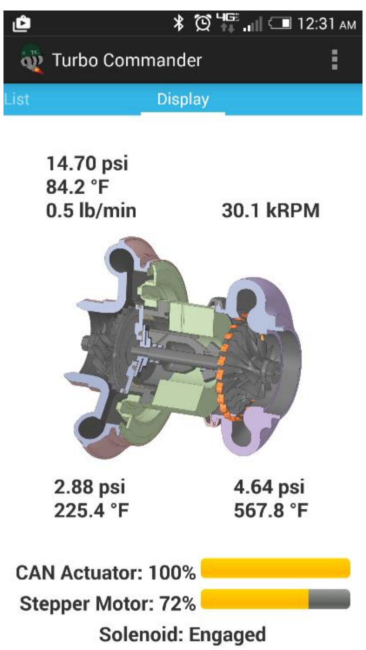
Once a Turbo Commander device is selected the connection will be made. When the Turbo Commander is out of range or power is disconnected, the app will report disconnected and return to the start screen.





Graphical Display Mode

The Turbo Commander app has a graphical display mode that enables a turbo-centric view of the data parameters instead of a list view. There are also position bars signifying the position of the actuators.



Demo Mode

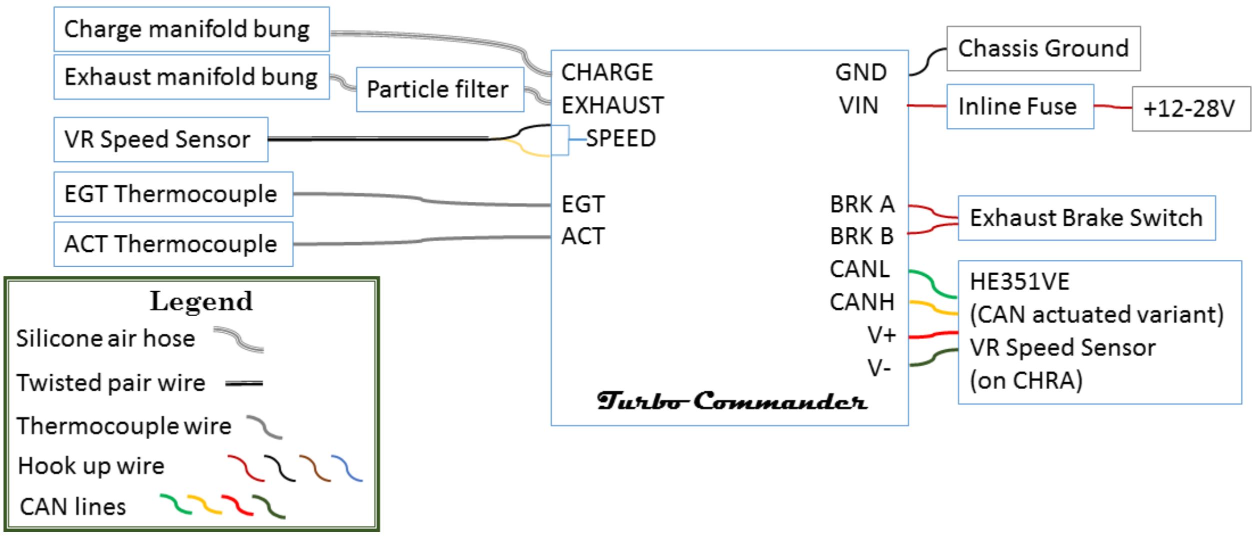
When the Turbo Commander app is not connected to a turbocharger, demo mode allows for display of app functionality as well as what a connected Turbo Commander looks like interacting with the app.

Application examples

HE351VE Basic Configuration

This example shows the configuration for a HE351VE turbocharger with a CAN bus actuator and several sensors used as safety limits.

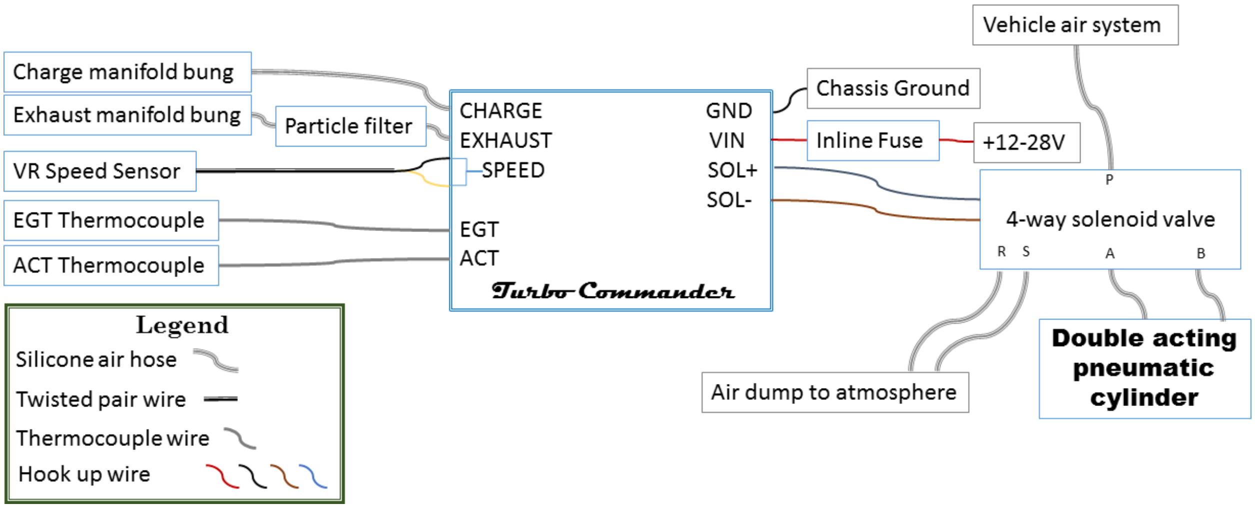
EXAMPLE WIRING DIAGRAM



Generic Double Acting Pneumatic Actuator Implementation

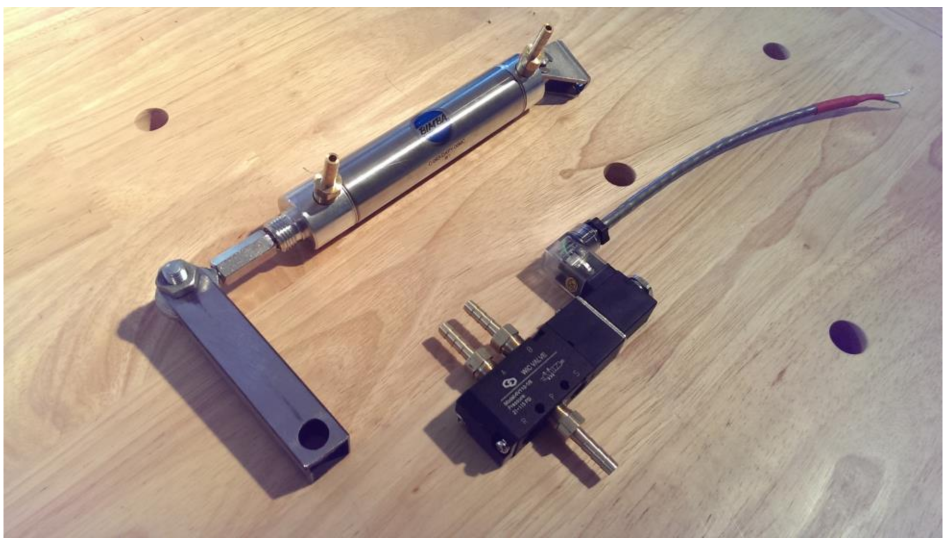
This setup shows the configuration for a generic double acting pneumatic actuator. This setup could be applied on any variable mechanism or turbocharger.

EXAMPLE WIRING DIAGRAM



PARTS LIST FOR THIS EXAMPLE

- Turbo Commander.*
- Inline Fuse.*
- Silicone hose. *
- Inline exhaust particulate filter.*
- Main terminal block connector.*
- Sensor terminal block connector.*
- EGT Thermocouple.*
- ACT Thermocouple.*
- VR Speed Sensor. (optional)
- Pneumatic 4-way solenoid valve. WIC Valve 4V110



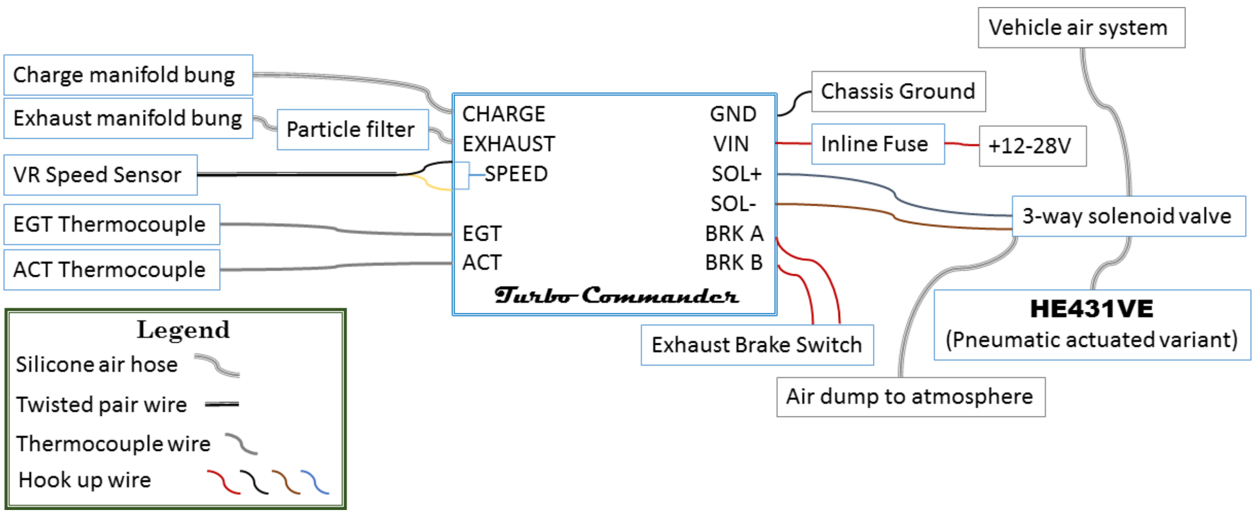
Pneumatic Actuator Implementation

This setup shows an installation for controlling a common variable turbocharger type using a pneumatic actuator. The main control loop in this example will be run from shaft speed sensor input and is modified by limits placed on the values from various additional sensors input to the Turbo Commander.

Features demonstrated:

- Shaft speed based control.
- EGT safety limit.
- ACT safety limit.
- Exhaust pressure safety limit.
- Charge pressure safety limit.

EXAMPLE WIRING DIAGRAM



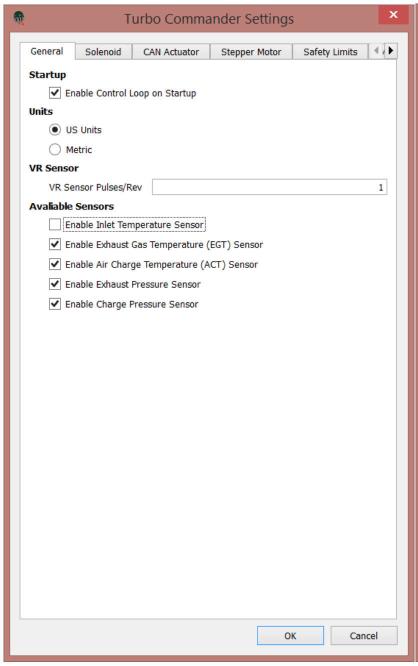
PARTS LIST FOR THIS EXAMPLE

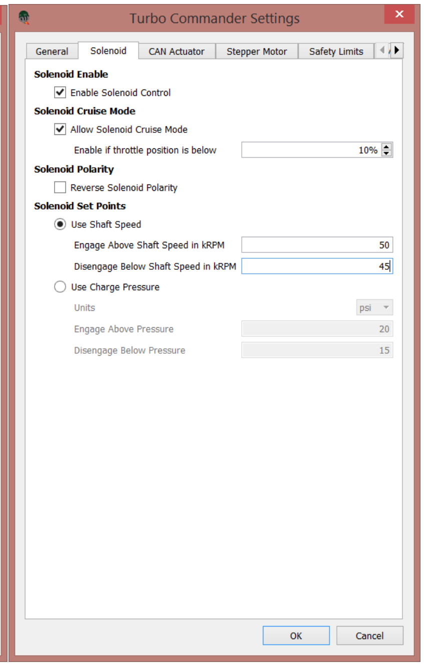
* Items included with the Turbo Commander Kit.

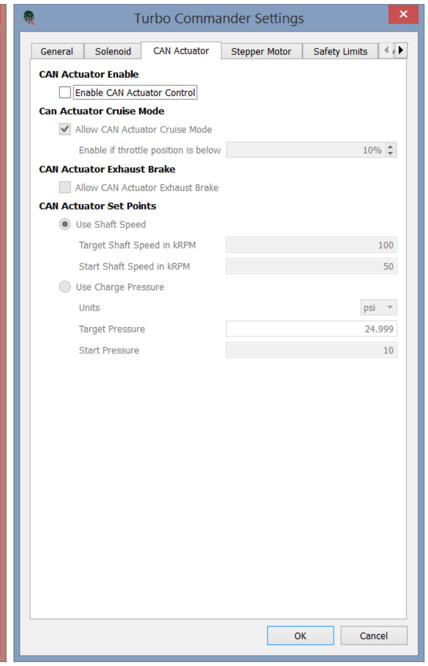
- Turbo Commander.*
- Inline Fuse.*
- Silicone hose. *
- Inline exhaust particulate filter.*
- Main terminal block connector.*
- Sensor terminal block connector.*
- HE431VE with pneumatic actuator.
- EGT Thermocouple.*
- ACT Thermocouple.*
- Pneumatic 3-way solenoid valve.
- Exhaust brake switch.*

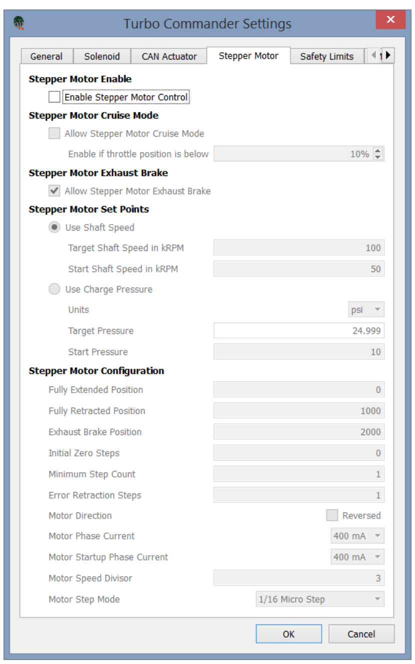
EXAMPLE SOFTWARE CONFIGURATION

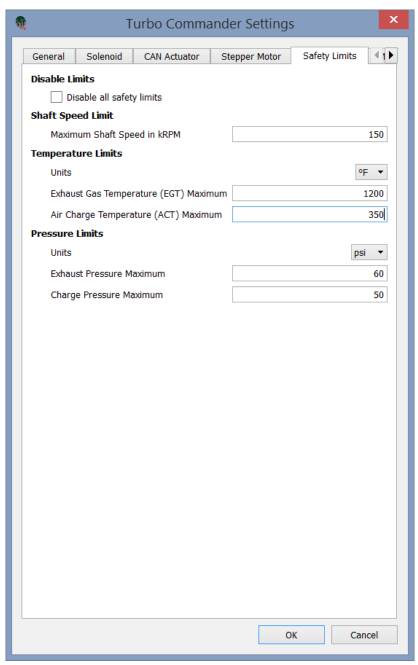
The frames below show the setup of the Turbo Commander Windows software that matches this example configuration.

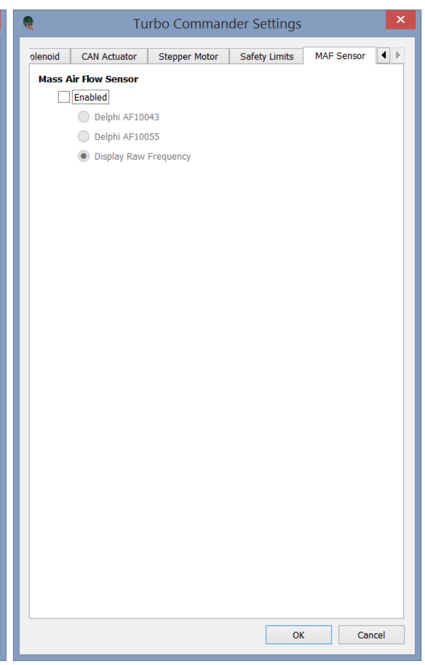












CAN Actuator with Water/Methanol Injection Implementation

This setup shows how easy it can be to implement a very advanced control system involving a VGT turbocharger and water/methanol injection control. The turbo commander can control the water injection system and meter the feed rate according to turbocharger conditions better than a stand-alone water injection system. This demonstrates a control implementation using three different actuators, a HE351VE CAN actuator, relay, and a stepper controlled proportional valve. The HE351VE is actuated over CAN bus, a relay is actuated to turn on a pump, and a stepper controlled proportional valve is set to control flow rate to a methanol/water injection nozzle.

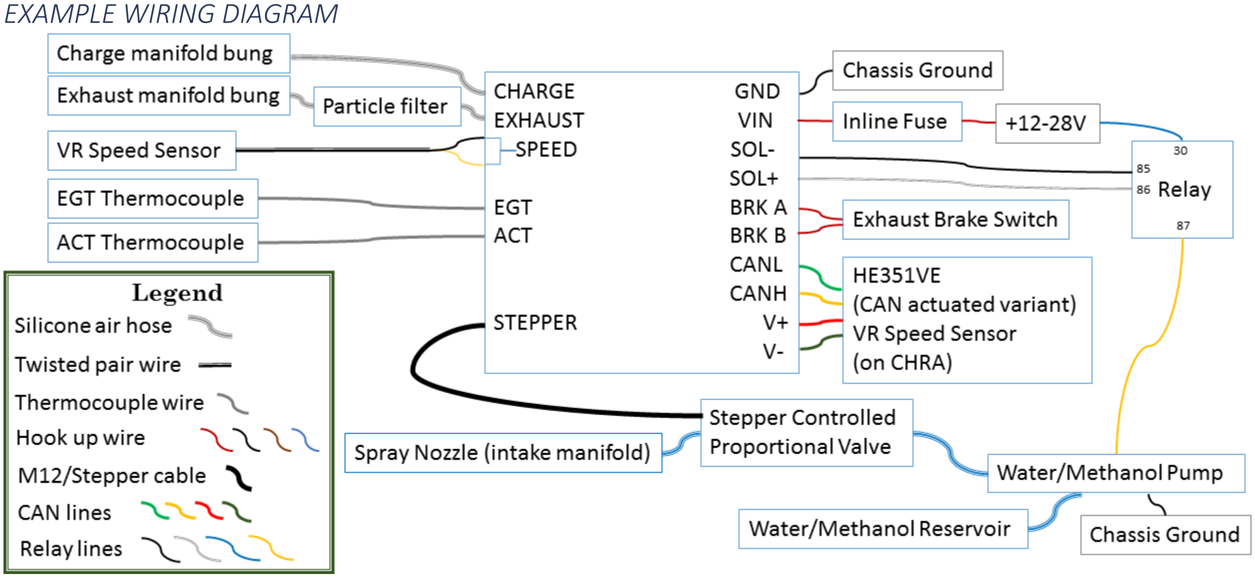
Features demonstrated:

- Charge pressure based control.
- EGT safety limit.
- Shaft speed safety limit.
- Exhaust pressure safety limit.
- Triple actuator control on different subsystems.
- Independent control of various actuators.

THEORY

The application of the VGT is elementary, however this implementation shows an additional concept of "chemical intercooling" using water to cool charge flow and prevent detonation.

EXAMPLE WIRING DIAGRAM



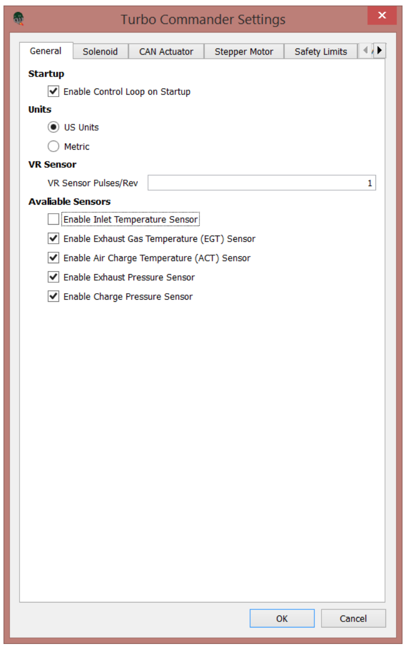
PARTS LIST FOR THIS EXAMPLE

- Turbo Commander.*
- Inline Fuse.*
- Silicone braided hose.* Trelleborg SF Medical CW100 Neutrasil Silicone NSF51.
- Inline exhaust particulate filter. *
- Main terminal block connector.*
- Sensor terminal block connector.*
- Water/Methanol pump with bypass regulator. AEM 310-484-2322
- Water injection spray nozzle. Various flow options, e.g. AEM or McMaster Carr spray nozzles
- Relay.*
- HOLSET HE351VE

- Clippard stepper controlled proportional valve. SCPV-1-3 with 1/8" NPT barbed connectors.
- EGT thermocouple*
- ACT Thermocouple.*
- Exhaust brake switch. Any SPST switch that fits the preferred cabin mounting location.

EXAMPLE SOFTWARE CONFIGURATION

The frames below show the setup of the Turbo Commander Windows software that matches this example configuration. Explanation is provided for all of the settings entered.

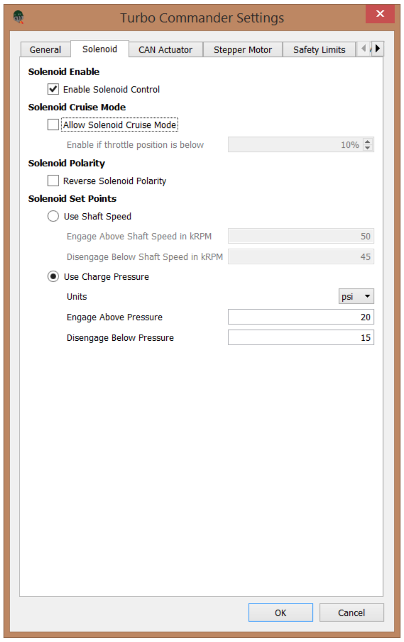


The software configuration starts with selecting the sensors that are being used in the application. In this example, there is an EGT sensor, ACT sensor, Exhaust Pressure, and Charge Pressure.

Display units preferences are selected in this tab. In this case we will use US units, because America.

The control loop should be enabled on device startup so that the actuators are being controlled according to the sensor readings.

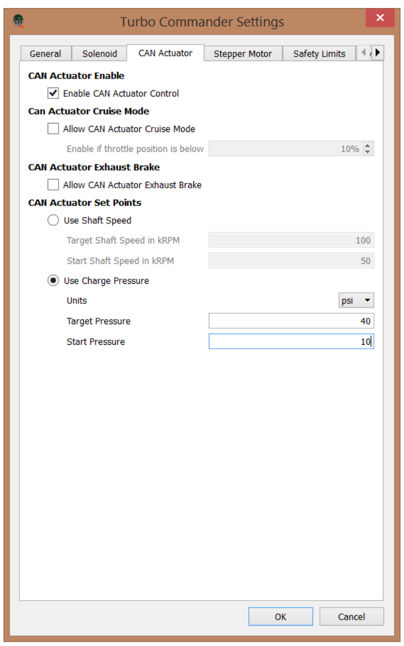
In this screen, there is also a value called VR Sensor Pulses/Rev. This value is entered according to how many times the VR speed sensor produces a pulse during one rotor revolution. In our case, the HE351VE in the example has a speed sensor on the CHRA with a single flat producing 1 pulse per revolution.



The solenoid tab has settings that are related to our relay in this example. A relay contains a solenoid and is actuated the same way as a solenoid valve. The Solenoid should be enabled by checking Enable Solenoid Control. Since we're using charge pressure for the control variable in this example, select Use Charge Pressure control.

Our goal is to actuate the relay to supply power and turn on the water/methanol pump before it's needed. However, we don't want it to be on all the time unnecessarily. The pump should turn on when boost is rising and the use of water injection becomes applicable. In this example we start the pump at 20psi.

To add hysteresis, the pump relay is told to turn off at or below 15psi when charge pressure is either falling or low. In other words, this difference between Engage and Disengage prevent the relay turning on and off rapidly with small fluctuations in charge pressure near the Engage setting.

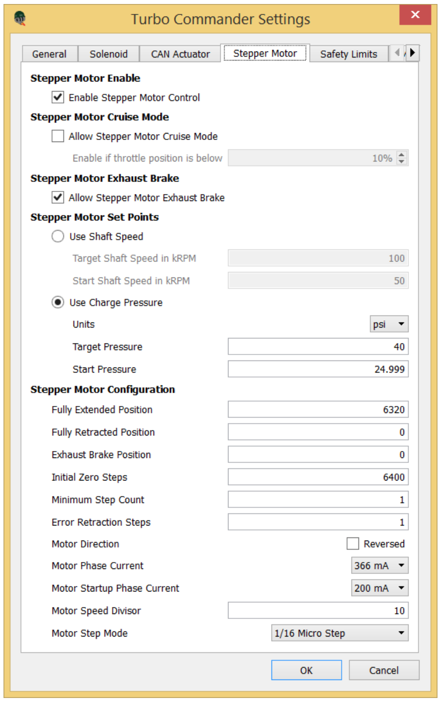


The CAN actuator is being used to control the HE351VE. This control system is also based on charge pressure, for the sake of this example.

The Start Pressure, as defined above, is the point at which the control system starts to engage the actuator to move the vanes between the maximum velocity and maximum flow condition. In this example we choose to start opening the vanes at 10psi.

Between Start pressure and Target Pressure the control system defines targets for the vane position.

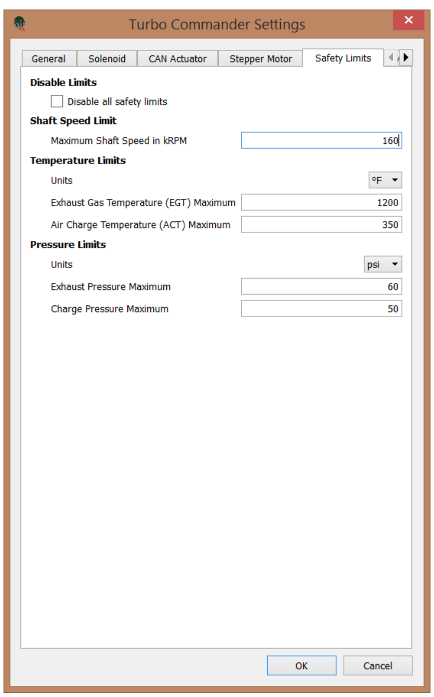
Once the Target Pressure is achieved or exceeded, the vanes are fully open.



The stepper motor is set up to control a proportional valve that meters the flow of the water/methanol. Our goal is to maximize flow at the target boost pressure of 40psi. However, we want to start opening the valve only after the pump has been started. Recall the pump was set to turn on at 20psi. Therefore, we'll start controlling this proportional valve at a higher value, like 25psi.

This valve has an open position of 395 steps and maximum stroke of 400 steps However, we're control freaks for the sake of this example and we want to step at 1/16 micro steps so we have excellent resolution over the flow rate. Therefore 16 times the full step value is what we want for our Fully Extended position (e.g. valve open). Thus, we'll set the Fully Extended position to 16*395 = 6320.

Initial zero steps is set to the value of the maximum valve stroke, so 400*16=6400. The initial zero makes sure that on startup the motor resets to its zero position. During initial zero, the motor phase current is set lower so the motor can snub against its limit without excessive force if the system lost power mid-stroke.



In this example, we'll also set up our safety limits based off of the sensors we have attached to the system. This is important to keep abnormal operating conditions from damaging the system or causing over speed and pressure conditions.

The maximum shaft speed is set to 160kRPM. Above this value, the turbo will immediately move to the maximum exhaust flow condition to lower velocity at the turbine.

The temperature limits are set up to respect both EGT and ACT readings. Typical extreme values are entered for a diesel motor.

Pressure limits are configured to 10psi over the target boost, and 20 psi over target boost for drive pressure.

Depending on the configuration of the engine, these parameters may differ but these values serve as a generic example.

Wiring Actuators

CAN BUS ACTUATOR

The Turbo Commander's CAN bus interface enables OEM turbocharger actuators to connect and receive commands. As the Turbo Commander user base grows, various CAN actuators will be added to expand capability of the device. At this time Holset VGT CAN actuators are supported.

When using a CAN actuator, make sure the power supply can source up to 10A of current. These actuators have a high instantaneous current draw because of their high power density BLDC motors. The CAN actuator will brown out and malfunction if the supply cannot provide the required current.

Wiring a Holset HE351VE

Red with Gray stripe (+12V)
Green with White stripe (GND)
Yellow (CAN +)
Green (CAN -)

STEPPER MOTOR ON M12 CORDSET

The M12 connector on the Turbo Commander is made by Franz Binder GmbH & Co. This connector is known to be compatible with Binder series 763 M12 cordsets. Suprock Technologies sells an M12 cable with the Turbo Commander. Additional examples include:

- PUR (chemical resistant) - Binder 79 3439 35 05
- PVC – Binder 79 3439 15 05

A standard industrial M12 male connector cordset can be attached to the Turbo Commander stepper actuator connector. The standard M12 cordsets contain wire colors that correspond to their position on the connector, removing ambiguity in wiring the cordset to your stepper motor of choice. Nothing needs to be done to the Turbo Commander connector to use a standard M12 cordset.

Examples of the connector pinout on standard M12 cordests, corresponding to color:

A two phase stepper motor actuator can be wired to the M12 cordset. In order to wire the actuator to the cordset, refer to the stepper motor data sheet to determine wire colors for each phase on the motor. In a stepper, the phases are often labeled as Phase X and Phase Y. In a standard industrial M12 cord set the wire colors correspond to the Turbo Commander stepper connection as follows:

Brown (Phase X Positive)
White (Phase X Negative)
Blue (Phase Y Positive)
Black (Phase Y Negative)
Gray (If the cordset contains this wire, No Connection)

When making the connection to the M12 cordset, it is advisable to use heat shrink tubing or inline crimp connectors to make a reliable connection between the stepper pigtail and the M12 wire.

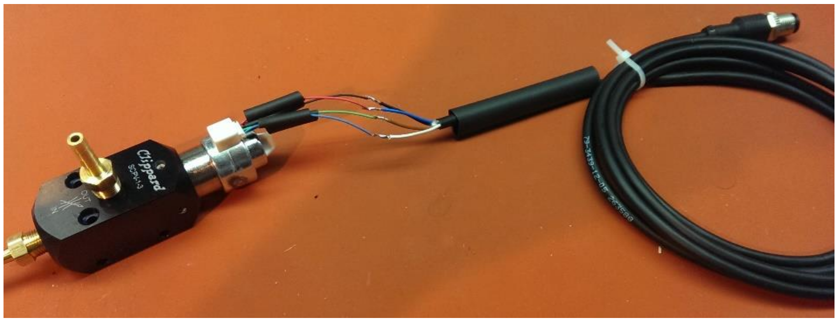
Wiring a stepper motor

Bipolar stepper motors are supported by the Turbo Commander. Steppers with more than 2 coils can be driven, if each set of phase coils are driven in parallel or in series.

Stepper Controlled Proportional Valve Wiring Example

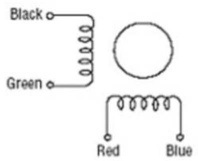
An interesting type of actuator that can be controlled through the stepper driver on the Turbo Commander is a stepper controlled proportional valve. This product is produced by Clippard and enables one of the exampes with methanol/water injection shown in this manual. The valve data sheet is available from http://www.clippard.com/

Stepper	M12 Cordset
Red	Blue
Black	**Black**
Green	Brown
Blue	White



In the picture above, a stepper controlled proportional valve is being wired to a Turbo Commander M12 cord set for use in the example.

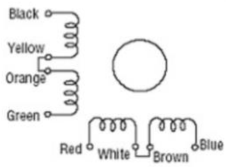
Stepper Wiring Example 1, 4 Lead Bipolar



The most basic bipolar stepper motor comes configured with 2 coils and 4 wires. This configuration is simple to connect to the M12 cordset. Based on the example wire colors given in the figure, the connections can be made following the chart below. Note, swapping phases will have the effect of physically reversing the motor rotational direction. If the movement direction is 'backwards' there is an option to reverse motor direction in the Turbo Commander software setup.

Stepper	M12 Cordset
Black	Blue
Green	**Black**
Blue	Brown
Red	White

Stepper Wiring Example 2, 8 Lead Bipolar Series

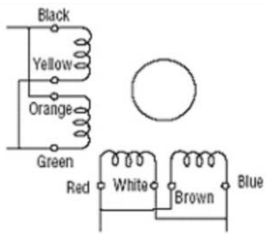


A slightly more complex wiring configuration can be achieved with an 8 lead bipolar series configuration. Based on the example wire colors given in the figure, the connections can be made following the chart below. In a series configuration, the coil wires can be connected in series for each phase. Note, swapping phases will have the effect of physically reversing the motor rotational direction.

Stepper	M12 Cordset
Black	Blue
Green	**Black**
Blue	Brown
Red	White

Stepper Wiring Example 3, 8 Lead Bipolar Parallel

The most complex wiring configuration for a bipolar stepper can be achieved with an 8 lead bipolar parallel configuration. Based on the example wire colors given in the figure, the connections can be made



following the chart below. In a series configuration, the coil wires can be connected in parallel for each phase. Note, swapping phases will have the effect of physically reversing the motor rotational direction

Stepper	M12 Cordset
Black/**Orange**	Blue
Green/Yellow	**Black**
Blue/White	Brown
Red/Brown	White

SOLENOID VALVE

A single coil solenoid valve can be wired to the Turbo Commander to actuate pneumatic or hydraulic actuator systems. This actuator can be used in a variety of configurations for push / pull actuated mechanisms.

Wiring a solenoid valve is straightforward. The two leads of the solenoid connect to the main connector at Solenoid + and Solenoid -. There is no setup required beyond connection.

Implementing an Exhaust Brake

If the exhaust break functionality is used, an exhaust brake switch can be installed. The most convenient way to achieve an exhaust brake implementation is to use a momentary switch that is actuated by the brake pedal assembly. This momentary switch can be put in series with a manual SPST switch so that the exhaust brake is automatically engaged during braking, but only when the driver feels that the exhaust brake is necessary.

Wiring exhaust break switches

Protecting the exhaust pressure sensor

When using an exhaust manifold pressure connection, be sure to elevate the Turbo Commander above the inlet. This will avoid soot deposits brought into the sensor by condensation and the convection/cooling of exhaust gas. Also, use the inline filter provided with the Turbo Commander kit to avoid soot contamination.

On the inline filter, there is an arrow which should point towards the Turbo Commander exhaust pressure inlet port.

The inline filter will serve an important role to keep soot from caking on the diaphragm of the internal pressure sensor inside the Turbo Commander. Exhaust is wet and full of carbon.

Installing a variable reluctance speed sensor

The subject of installing a variable reluctance (VR) speed sensor in a turbocharger is discussed for reference. The theory of a variable reluctance sensor is a permanent magnet wrapped with a coil of wire generating of a voltage pulse when the magnetic field is disturbed by magnetic material passing through the flux of the magnet. Toothed wheels, keyways, or any irregular feature in a rotor can excite the sensor. Because of the theory of operation, ferromagnetic materials work best with a VR sensor. Although these sensors are designed with magnetic materials in mind, they function acceptably with any conductive material if the relative velocity between the sensor and passing material is high. This is because eddy currents in the passing material interact with the permanent magnetic field and cause a voltage signal to be induced in the sensor coil.

Some turbochargers come with VR shaft speed sensors pre-installed in the CHRA. An example of pre-installed VR sensors are Holset brand turbochargers sold on specific models of engine. However, the majority of turbochargers do not come with a speed sensor installed. Therefore, if the speed sensor is a desired control or measurement input, the VR sensor must be installed into the turbocharger. While there are various acceptable ways of installing this sensor, the following techniques are known solutions.

The first method of installing a VR sensor is through the compressor housing at the turbocharger inlet. This positions the tip of the sensor to monitor pulse counts on the compressor wheel retaining nut. This method is convenient for engine configurations such as Subaru EJ series engines, where the turbo is tightly integrated with the surrounding engine components. One compromise of this position is the introduction of the VR sensor into the compressor inlet flow path, although air velocity in the inlet is not enough to cause disruptive turbulence from the VR sensor body. *Engine dynamometer testing has shown no detriment from introduction of the sensor in this configuration.* Sensor diameters in this scenario should be as small as possible, such as ¼” threaded VR sensors. It is recommended to only use a stainless steel body threaded VR sensor in this configuration.

The figures below show installation of the sensor on a TD05H turbocharger.

A second method of installation takes advantage of the turbocharger compressor blades as the excitation for the sensor. In this scenario, the sensor is mounted in the compressor housing so that the tip of the sensor is pointing at an area of the turbocharger wheel with significant thickness. A good position tends to be the blade radius between the inducer and exducer diameters. In order to ensure the sensor locates in a position that does not disrupt turbocharger fitment in the engine bay, this method of installation requires more planning and measurement than the compressor inlet method. **A key tip with installation of a VR sensor at the turbocharger compressor blades is to drill the hole from the inside of the compressor housing so that the hole pilots at the correct angle and location.** Complications with this method can be deep tapped holes intersecting voids in the casting or intersection of the hole with internal features such as surge bypass rings.

Although this installation technique is more complex, the advantage is that there is no obstruction to the inlet flow path. This may be useful on applications where extreme flow rates are expected or in certain types of race classification where specific flow restrictors are required in the turbocharger inlet.

The figures below show installation of the sensor on S300 and GTX3582 turbochargers.

VR Pulses per revolution

Depending on the physical configuration, you will have to configure how many pulses per revolution are being seen by the VR sensor. This is available in the software configuration, discussed below. The way to do this is to count how many pulses (peaks) are seen by the VR sensor. For example, the configuration with the Holset 351VE OEM VR sensor registers 1 pulse per revolution (the sensor reads a flat machined on this turbocharger cross shaft). Another example is the VR sensor reading the compressor hex nut where there are 6 pulses per revolution. Finally, in the case of reading compressor wheel buckets, the number of buckets/blades is equal to the pulses per revolution.