1. SOFTWARE & CONTROLS

The Mustang GEN-4 control system is member of Mustang's latest generation of embedded micro-controller based dynamometer control systems. All control and monitoring functions are performed by an embedded 16 bit digital micro-controller. All calibrations are performed using the on-board LED, or enclosure mounted LCD display and keyboard, with calibration values stored in on-board, non-volatile FLASH memory. Testing values, such as load or speed set points, can be entered by the operator in exact unit values. Mustang's GEN-4 control system provides faster and more stable loading control than previous analog control systems, and is wirelessly interfaced to a laptop computer to provide data logging and advanced control functionality.

Using the state of the art micro processor based controls connected to the tow dynamometer, it is possible to test vehicles and simulate road profiles taken from pre-recorded data of road grades, hills and mountains. All of this testing can be performed without leaving the safe, controlled confines of the test track. Mustang's software allows the test engineer to develop grade, load, speed, and vehicle simulation profiles vs. time or distance at their desk and down load them to the dynamometer controller. The dynamometer controller can switch between control modes during any of these tests.

The available control modes include:

- Manual control
- Constant force (draw bar)
- Constant speed
- Constant power
- Vehicle simulation (A, Bv, Cv^2, weight, grade)
- Script Testing: Script testing allows the operator to create unique test cycles based on time or distance. The operator can easily configure the software to change between control modes while the dynamometer is executing the test cycle.

Example : The operator would like to load the towing vehicle at:

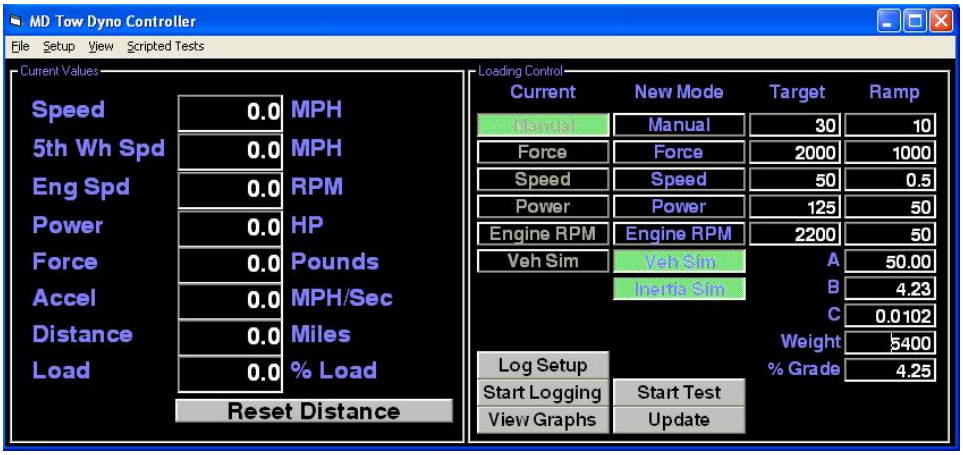
Load of 5,000 N for 1 km, then switch to:

Hold vehicle at constant speed of 10 km/hr for 1.5 km, then

Simulate the vehicle climbing a grade for 0.5 km.

The operator would create a script, which holds constant force of 5,000 N for 1 km. After the 1 km has been travelled, the software automatically switches to a speed control mode of 10 km/hr for 1.5 km. After the 1.5 km has been travelled, the software will then switch to vehicle simulation control mode, and load the vehicle to the appropriate grade selected for 0.5 km.

The operator uses a laptop computer as the operator interface. The software allows for data logging, graphical review, and data exporting. For the advanced user, the operator can configure screens, store them, and recall them as needed. The laptop PC communicates the set points to the tow GEN-4 control system located in the trailer. The information sent by the laptop/software is used by the embedded 16 bit digital micro-controller to control and configure the tow dynamometer. The calibration and set-up information are stored in flash memory. A wireless interface allows communication between the GEN-4 controller and the laptop PC. This interface allows for easy movement of the vehicle and the tow dynamometer.



Mustang's standard control systems are equipped with dynamometer controls and data acquisition, and can easily be upgraded with a data pod to acquire additional information required by the operator. The data pod is available in a standard configuration with 16 analog inputs. The Data Plus-1 extended system provides up to 128 data channels and the Data Plus-2 system provides over 1,000 channels.

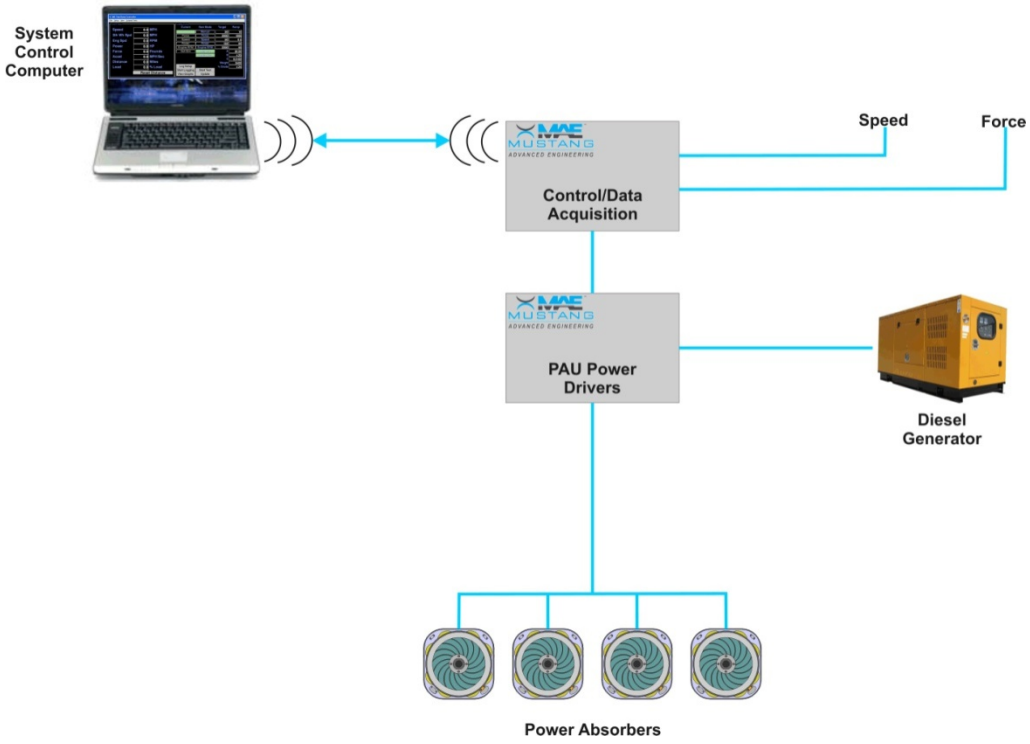


FIGURE 1 - CONTROL SYSTEM SINGLE LINE DIAGRAM

2. STANDARD FEATURES

- Manual, Constant Torque, Constant Speed, Constant Power, Vehicle Simulation, Grade Simulation, and Trailer Weight Simulation modes.
- Easy to use data acquisition and graphing capabilities.
- Metric or Imperial units.
- Time or distance based scripting.
- One click script execution.
- OBDII, J1708, and J1939 support.
- Convenient wireless operation. Wired operation is also supported via 30' Ethernet cable (included).
- Seamless capability to control multiple tow dynamometers (allows daisy chaining dynamometers).
- Easy to use script builder.
- Simple 'one click' calibration procedure.
- Driver's aid.
- Touchscreen.
- Open loop scripting for testing cruise control systems.
- Real time grade compensation available.
- Compliant with Nebraska Tractor Test Procedures.
- Compliant with Chinese National Testing Standard GBT 12537-1990.
- Compliant with Bureau of Indian Standards IS 5994:1998, 12036:1995, and 12226:1995.
- Excel compatible import & export.
- 'Plug & Play' controller support for fleets allows any controller to be used with any tow dyne.
- CAN bus output (DB-9) with database configuration file.
- 16 bit, 1 MHz commercial data acquisition module.
- 16 analog inputs with thermocouple support (easily expandable to 64 analog inputs).
- Four (4) 16 bit, 1 MHz analog outputs, 0-10 VDC for speed, force, and two spares.
- 24 high speed digital I/O channels.
- Four (4) 32 bit counter input channels with quadrature encoder capability.
- Overspeed and PAU overtemp protection standard.

3. COMMON OPTIONS

3.1. OBDII/CAN INTERFACE

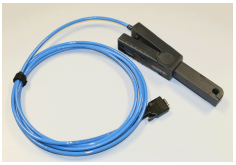
The tow dynamometer control system can interface to the test vehicle via a CAN/OBDII adapter. A vehicle database file is required to decode the vehicle data from the CAN information. The OBD-II module is a direct connection to the vehicle's OBD-II port and allows capture of virtually every critical parameter directly from the vehicle's ECM.

3.2. ENGINE RPM MEASUREMENT SYSTEM

The SmartTach is a precision speed measurement instrument designed specifically for the development and testing environment. Among its many innovations is the capability to continuously measure speed from virtually any type of signal. From distributor or coil pack-type gasoline engines to diesel engines to electric motors, the SmartTach's flexibility makes it truly universal. The SmartTach reads any pulse input from a wide range of sources such as magnetic sensors, encoders, Electronic Control Unit outputs or ignition coils.

- Inductive RPM Pickup Sensor: Measure engine speed by clamping the Inductive Pickup Sensor around a Secondary Ignition cable. While traditionally used on a Spark Plug wire, it can also be used on a coil wire to achieve improved measurement response.

- TachSensor: The TachSensor is available for those situations where measurement of engine speed via an inductive probe is required. Just clamp the TachSensor around an Ignition Primary wire anywhere between the coil and the Electronic Control Unit.



- Optical RPM Pickup Sensor: The Optical RPM Pickup works by monitoring light as it bounces off of a piece of reflective tape applied to a rotating object. Unaffected by electromagnetic interference, the Optical RPM Pickup works in many applications where inductive pickups may not.

3.3. AUTOMATED ADJUSTABLE HITCH (MOBILE STYLE ONLY)

The tow dynamometer can be equipped with a vertically adjustable front hitch assembly. The front hitch assembly can accommodate hitch heights of 400 to 1,200 mm (standard, other dimensions available). The hitch assembly includes an integrated load cell to accurately measure drawbar force. The hitch assembly can also be equipped with an optional integral steering system which allows the tow dynamometer to be operated without a driver.

3.4. FIFTH WHEEL ADAPTER

Fifth wheel adapters are available for testing Class 8 trucks.

3.5. FUEL CONSUMPTION MEASUREMENT SYSTEM

The tow dynamometer can be delivered with an integrated fuel flow measurement system to measure the fuel burn rate on small to medium sized diesel engines. The fuel measurement system includes a heat exchanger and fuel pump to cool the warm fuel from the return fuel line.

- 1.05 - 69 gph measurement range
- 15.2 - 1,000 HP
- ±1% accuracy
- 0 - 185° F fuel temperature range

3.6. WEATHER STATION

The tow dynamometer can be equipped with a weather station which provides ambient temperature, barometric pressure, and relative humidity.

- Barometric pressure range 50 - 1,100 hPa
- Barometric pressure accuracy ±0.45 hPa
- Relative humidity range 0 - 100% RH
- Relative humidity accuracy ±1% RH
- Temperature range -40 - 140° F
- Temperature accuracy ±0.4° F

3.7. PORTABLE EMISSIONS MEASUREMENT SYSTEM (PEMS)

The PEMS system utilizes a miniaturized multi-chamber, and replaceable “Sensor Cartridge” (patents pending) design to obtain second-by-second PM/PN data from diesel engines. A new NOx/CO2 GasMOD™ sensor cartridge expands the testing capabilities for light and heavy duty diesel.

PEMS unit features opacity, scattering, ionization, sizing, speciation, NO, NO2, and CO_2 measurements.

3.8. VBOX GPS SYSTEM

The Racelogic VBOX is one of the best known and highly valued test instruments for non-contact speed and distance measurement. Using a powerful GPS engine, the VBOX logs data at 100 times a second and features a 400 MHz power PC processor. With IMU integration, USB and Bluetooth connectivity, compact flash card logging and audio functionality for voice tagging, the VBOX represents a flexible solution to a range of testing requirements.

The VBOX features a powerful GPS engine capable of providing 100 Hz update rate for all GPS parameters (including velocity and grade). Velocity and heading data are calculated from Doppler Shift in the GPS carrier signal, providing users with unparalleled accuracy.

Integrating the VBOX provides users with a means of easily creating real world driving simulations on a test track.

3.9. FIFTH WHEEL SPEED SENSOR

The fifth wheel sensor is accurate, reliable, rugged, and easy to use. The fifth wheel features a high resolution optical encoder and low tire diameter growth to ensure excellent accuracy. A helical torsion spring allows a compact design and provides surface tracking by keeping the wheel in contact with the ground during dynamic maneuvers.

The fifth wheel is ruggedly constructed from high strength materials and precision components. Originally designed for use in the “high-G” environment of vehicle crash testing, the fifth wheel has also performed well in many less demanding applications including low speed measurements over rough terrain.

- Temperature range: -40° to 212° F (-40° to 100° C)
- Speed range: 0 to 80 mph (0 to 129 km/h)
- Speed accuracy: <±0.2 mph (<±0.3 km/h)
- Tire growth: <0.5% at 50 mph (80 km/h)

3.10. ADDITIONAL I/O

Mustang can provide many other I/O points and associated sensors to the tow dynamometer control system. Please consult with a sales engineer regarding your specific application. The most common additions include:

- Temperature sensors
- Pressure sensors
- Wheel speed sensors (to perform wheel slip testing)

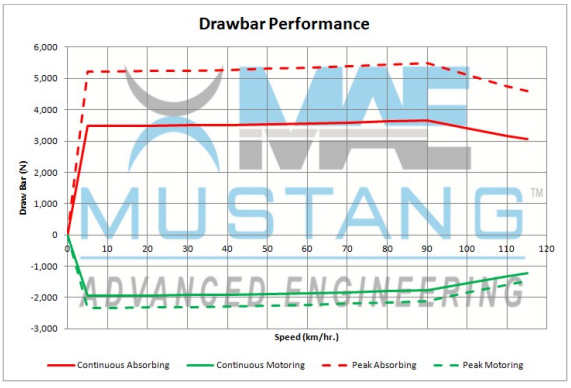
3.11. PAU COOLING FANS

PAU cooling fans can be supplied to assist in maintaining proper operating temperature of the PAU(s). PAU cooling fans are recommended, especially for high load/low speed testing applications and high temperature testing environments.

- Diameter: 24" (610 mm)
- Motor: 3 HP (2.2 kW), 1,750 rpm, TEFC
- Air flow rate: 10,200 cfm (4,810 l/s)

3.12. E-SERIES PUSH/PULL

Mustang's E-Series tow dynamometers provide the ability to not only accurately simulate uphill grades, but to also simulate downhill grades and to provide zero drawbar force. Mustang offers E-Series tow dynamometer models designed for testing a wide range of vehicles; from compact cars to off-road trucks. The Mustang E-Series tow dynamometers offer performance benefits not found on competitor's machines; absorbing time (uphill simulation) only limited by generator fuel supply, motoring (downhill and zero drawbar simulation) only limited by fuel supply.



3.13. PTO LOADING SYSTEM

A PTO Input loading system is also available with integrated speed and torque measurements. The PTO loading system can be used while the towing dynamometer is operating. The following table depicts the various control modes available. ***Please note the values are shown for example only, actual values will be dependent upon the tow dynamometer purchased.***

TABLE 1 - TOWING MODE ONLY (NO PTO)

CONTROL MODE	TOWING	PTO
Manual (wheels)	0 - 100%	NA
Manual (PTO)	NA	None
Speed (wheels)	2 - 100 km/h	NA
Speed (PTO)	NA	None
Force (drawbar)	300 - 80,000 N	NA
Torque (PTO)	NA	None
Power (drawbar)	11 - 224 kW	NA
Power (PTO)	NA	None
Polynomial f(km/h)	F(a, b, c, $v_{km/h}$)	NA
Polynomial f(rpm)	NA	None
Engine RPM f(force)*	500 - 3,000 rpm	NA
Engine RPM f(torque)*	NA	None

TABLE 2 - PTO MODE ONLY (NO TOWING)

CONTROL MODE	TOWING	PTO
Manual (wheels)	None	NA
Manual (PTO)	NA	0 - 100%
Speed (wheels)	None	NA
Speed (PTO)	NA	100 - 1,500 rpm
Force (drawbar)	None	NA
Torque (PTO)	NA	27 - 27,000 N-m
Power (drawbar)	None	NA
Power (PTO)	NA	11 - 224 kW
Polynomial f(km/h)	None	NA
Polynomial f(rpm)	NA	F(a, b, c, v_{rpm})
Engine RPM f(force)*	None	NA
Engine RPM f(torque)*	NA	500 - 3,000 rpm

TABLE 3 - MIXED MODE

CONTROL MODE	TOWING	PTO
Manual (wheels)	0 - 100%	NA
Manual (PTO)	NA	0 - 100%
Speed (wheels)	2 - 100 km/h	NA
Speed (PTO)	NA	100 - 1,500 rpm
Force (drawbar)	300 - 80,000 N	NA
Torque (PTO)	NA	27 - 27,000 N-m
Power (drawbar)	11 - 224 kW	NA
Power (PTO)	NA	11 - 224 kW
Polynomial f(km/h)	F(a, b, c, $v_{km/h}$)	NA
Polynomial f(rpm)	NA	F(a, b, c, v_{rpm})
Engine RPM f(force)*	500 - 3,000 rpm	NA
Engine RPM f(torque)*	NA	500 - 3,000 rpm

**** Requires optional engine RPM interface.***

Sample values shown to depict control mode capability, actual values may be different based upon unit purchased.

Some control modes may not operate simultaneously due to test vehicle and/or tow dynamometer limitations such as Engine RPM f(force) and Speed (PTO).