A Brief Study Analyzing the Effects that Throttle Mapping have on Engine Output on the MS3

This analysis has been put performed to help us and the Mazdaspeed3 (MS3) community understand the varying effects that the throttle angle, throttle mapping, and throttle control have on the power output of the USDM MS3 engine. We are hoping to be able to prove various points and answer the following questions by analyzing the test results:

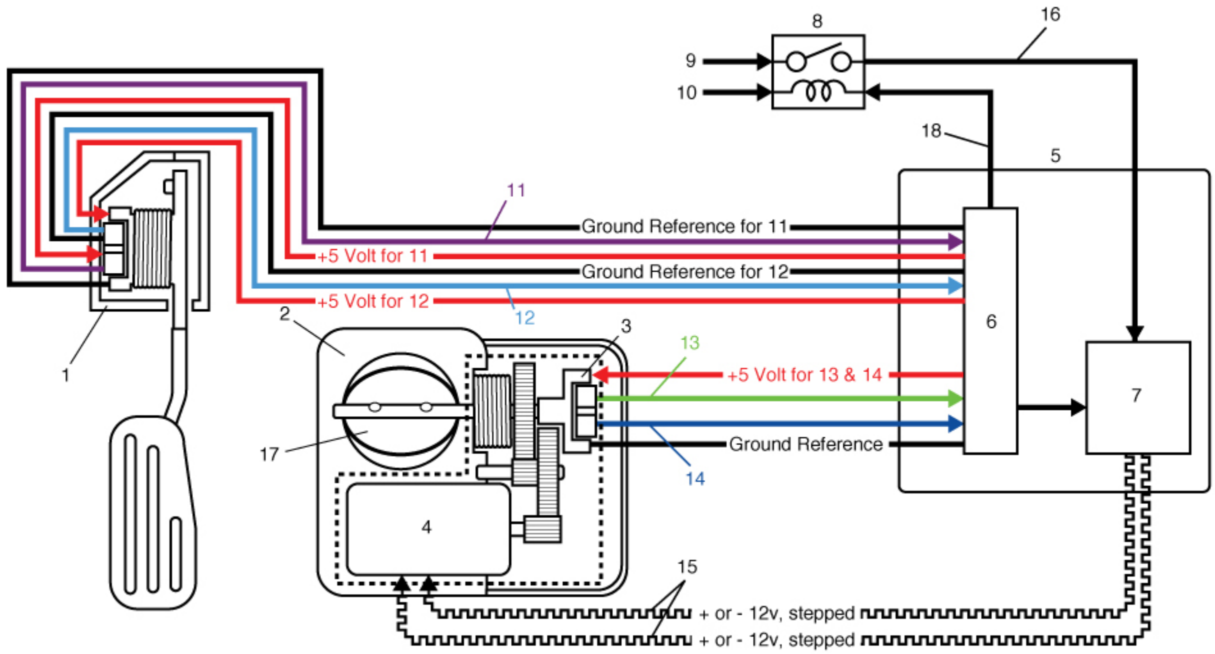
Does Cobb Tuning have full control of the throttle system on the MS3?

Does running the throttle system on full duty cycle all the way to redline increase the power output of the MS3 engine?

Is the programmed throttle closing a detriment to the power output of the MS3 engine?

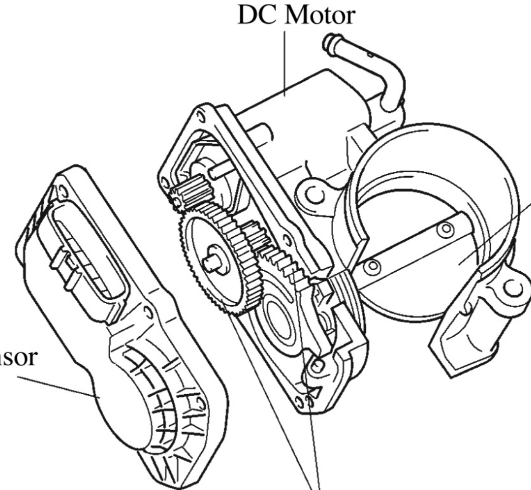
Is the closing of the throttle prior to the engine redline the main reason for the drop-off in engine torque production?

For an introduction, we feel it would be best to review how the DBW (Drive-By-Wire) system operates. This information has been taken from COBB Tuning's EFI 102 class material.



1. Accelerator Pedal Position (APP) sensor assembly, which contain the accelerator pedal and two separate APP sensors; APP Main & APP Sub		
2. Electronic throttle body assembly, which contains the throttle valve, throttle actuator motor, and two throttle position sensors; TPS Main & TPS Sub		
3. Throttle Position Sensors (TPS)	9. From "throttle motor" fuse	15. Drive signals for throttle actuator
4. Throttle actuator motor	10. From main relay	16. Power supply for throttle actuator, +12v
5. Engine Control Module (ECM)	11. APP Main sensor signal	17. Throttle valve
6. CPU	12. APP Sub sensor signal	18. Control signal for throttle actuator control relay
7. Drive circuit for throttle actuator	13. TPS Main sensor signal	
8. Throttle actuator control relay	14. TPS Sub sensor signal	

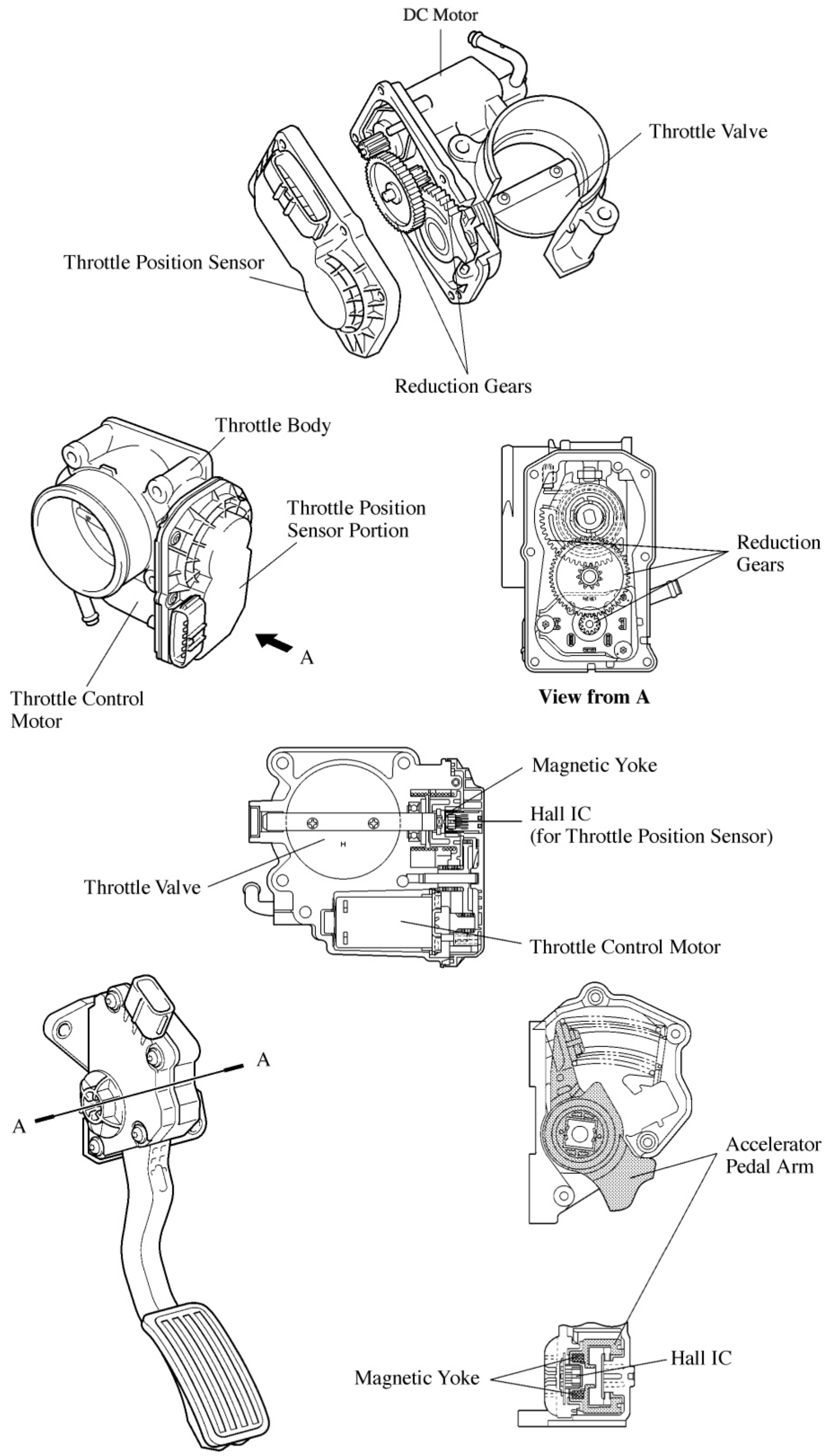
The Throttle By-Wire (TBW) aka Drive-By-Wire (DBW) systems appears to be more complex than they actually are due the the redundancy which is built into the systems for safety reasons. Most TBW systems contain four major components; (1) the Throttle Actuator Control Relay, (2) the Drive Circuit for the throttle actuator which is located inside the ECU, (3) the Accelerator Pedal Position (APP) assembly, and (4) the Electric Throttle Body Assembly. With the implementation of the TBW system, manufacturers were able to eliminate the Idle Air Control (IAC) system because they are able to use the electronic throttle body to control the engine's deceleration and idle. The above diagram will demonstrate the basic TBW system operation, please notice that each sensory component of the TBW system has 6 wires connected to it; we will later explain what each of these wires are for.



The first part of this system is the Throttle Actuator Control Relay which powers and protects the TBW circuity. The second part of this system is the Accelerator Pedal Position (APP) assembly which transmits two pedal position inputs to the ECU. The gas pedal (APP assembly) is effectively two independent pedal position sensors which each contain a +5V reference, a ground reference, and a signal which is sent to the TBW circuitry located inside the ECU. One signal is considered the “Main” APP signal and the secondary signal is considered the “Sub" APP signal, both of which tell the ECU what the driver's foot is doing as far as requesting torque from the motor (how much the driver is pushing down on the gas pedal).

The next part of this system is the Electric Throttle Body Assembly which consists of the throttle actuator motor, throttle valve, and 2 throttle position sensors. Like the APP assembly this part contains 6 wires; two of which are the shared +5V reference and shared ground reference wires which power the two TPS sensors, The next two wires are the redundant TPS sensor signals (Main and Sub) which transmit the position of the throttle blade to the ECU. The last two wires are for the throttle actuator control signal, these lines control the opening and closing of the throttle blade.

The last part of this system is the TBW Circuitry located inside the ECU. This circuitry receives the Main and Sub APP signals so it knows what the driver's foot is doing (as far as requesting torque) then it sends a square wave, 12 volt signal across the two throttle actuator control signal lines to step the throttle actuator motor with a duty cycle; 100% duty cycle would open the throttle blade to WOT & 0% duty cycle would keep the throttle blade at the fully closed position. Based on the feedback received from the two TPS sensor signals located in the Electric Throttle Body Assembly, the TBW system is constantly receiving inputs (APP & TPS) and controlling outputs (throttle actuator motor) in order to control the throttle blade movement on the vehicle.



What this means to you:
...most modern engines will never show a 0% TPS since the throttle blade is always kept open (by

2-7%) to start the engine and to maintain idle.
...some modern engines will never report a 100% TPS while at WOT since their TBW system may have been programmed to only open up to a predetermined point.
...you can change the Rev Limits on an engine by tricking the ECU about the reported RPM but you may not be able to get the motor to accelerate past a certain RPM since the throttle body has been programmed to close by a predetermined RPM.
...porting of most modern throttle bodies is not a good idea unless you have the ability to fully re-calibrate that system.
...most modern engines will not allow the motor to start immediately after the battery has been disconnected then re-connected or if the ECU has been re-set because the systems needs approximately 5 seconds to fully calibrate the TBW system. If the battery has been disconnected then re-connected or if the ECU has been re-set, please allow the key to stay in the ON position for a minimum of 10 seconds to allow the TBW system to calibrate before you try to start the engine.
...providing a constant +12V to the throttle actuator motor will fully open the throttle blade, providing a constant -12V (reversing the polarity) to the throttle actuator motor will fully close the throttle blade.
...most modern EMS logic has been calibrated to control the throttle blade opening and closing speed. We have seen where the throttle blade actually opens slower if you slap down the gas pedal versus gradually depressing the gas pedal.
...most modern EMS programming was established to lessen the emissions output of the motors, so throttle opening and closing delays have been implemented to lessen the emission output of the motors...not to piss you off.
...most modern vehicles have some sort of Traction Control System which use the Electric Throttle Bodies to control engine torque output.
...most modern vehicles have some artificial throttle response programmed into their control. For instance, if the driver is pushing down on the APP 20% the TPS sensor may report a 50% reading. The ECU is creating artificial throttle response by opening the throttle valve much more that the driver is requesting.

Miscellaneous Tables: Throttle Duty Cycles

RPM \ Throttle Position	0	10	18	27	33	39	49	55	62	65	68	72	86	93	100
800	0.00	29.75	50.00	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
1200	0.00	26.75	50.00	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
1600	0.00	25.00	50.00	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
2000	0.00	23.75	50.00	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
2400	0.00	21.75	52.50	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
2800	0.00	21.00	55.00	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
3200	0.00	17.75	51.25	63.00	66.50	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
3600	0.00	17.50	47.50	62.75	65.25	69.75	73.25	76.50	80.00	83.25	86.50	90.00	93.25	96.75	100.00
4000	0.00	17.00	47.00	62.50	64.75	69.25	72.75	76.00	79.50	83.00	86.25	89.75	93.25	96.50	100.00
4400	0.00	16.75	45.00	61.25	64.00	69.00	72.50	75.75	78.75	81.25	85.00	88.75	92.50	96.50	100.00
4800	0.00	16.25	43.75	58.75	63.25	68.75	71.25	75.00	77.50	80.00	83.75	87.50	91.25	96.50	100.00
5200	0.00	15.25	40.00	56.25	62.50	67.50	70.00	73.75	75.00	77.50	81.25	86.25	90.00	96.50	100.00
5600	0.00	15.25	35.00	51.25	61.25	65.00	67.50	71.25	72.50	75.00	78.75	85.00	88.75	96.50	100.00
6000	0.00	15.25	30.00	46.25	57.50	61.25	63.75	68.75	70.00	72.50	76.25	83.75	88.75	96.25	100.00
6800	0.00	15.25	20.00	36.25	48.75	52.50	55.00	61.25	65.00	67.50	71.25	78.75	88.75	95.75	100.00
6900	0.00	15.25	20.00	36.25	48.75	52.50	55.00	61.25	65.00	67.50	71.25	78.75	88.75	95.75	100.00
7000	0.00	15.25	20.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00

Throttle Duty Cycle

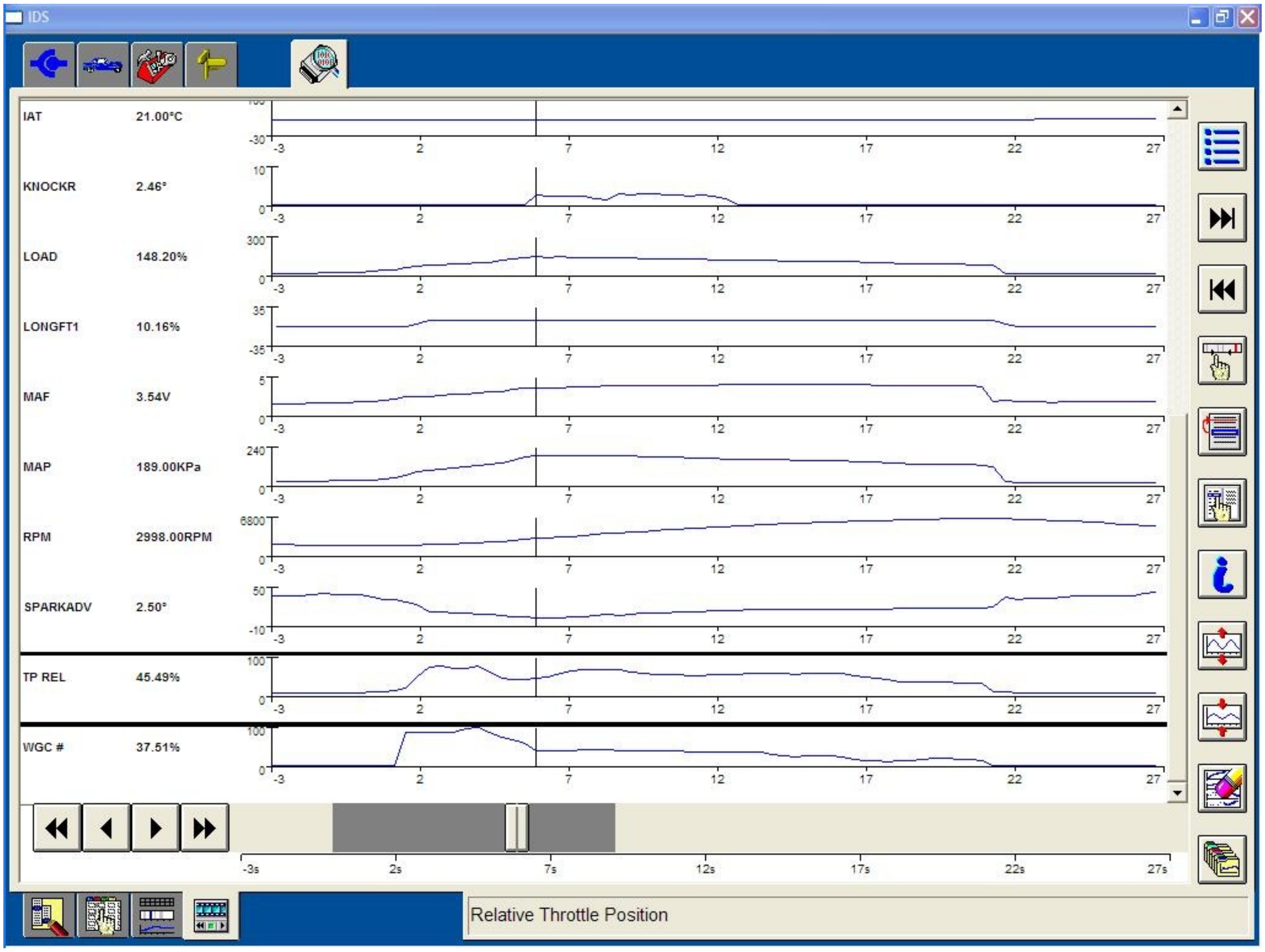
The above matrix is an example of an ECU table used to control the electronic throttle body system (this is NOT the MS3 throttle control table). As you can see the Y-axis breakpoints are engine RPM and the X-axis breakpoints are APP sensor signal inputs. The ECU logic is going to look up what duty cycle it wants to step to the electronic throttle body motor based on these two inputs, APP and RPM. It will then use the logic programmed in the on-board PID system to control the mechanical DBW components. Most TBW systems operate in an closed-loop condition where feedback is given to this sub-system and this sub-system will use programmed corrective measures to properly control the throttle blade. Notice how the ECU has been calibrated to shut the throttle duty cycles down to 25% by 7000 RPM, this is done to further protect the motor from an overrev or overrun event. The calibration of this table can dramatically change how a vehicle drives.

Now that we reviewed the DBW system would feel it is best that we demonstrate that we have *full* control of this system on the Mazdaspeed3. In order to do this we have created four different calibrations that were sequentially run on our Mustang Chassis Dynamometer. These calibrations were programmed as follows:

FTCvA = contains stock throttle mapping
FTCvB = was programmed to cycle between full throttle duty cycle and 25% of full duty cycle (75% less duty cycle) starting at 3000 RPM
FTCvC = forces the throttle system to maintain full throttle duty cycle all the way to redline
FTCvD = maintains a throttle duty cycle that is 50% of full duty cycle (in other words the throttle was 50% closed)

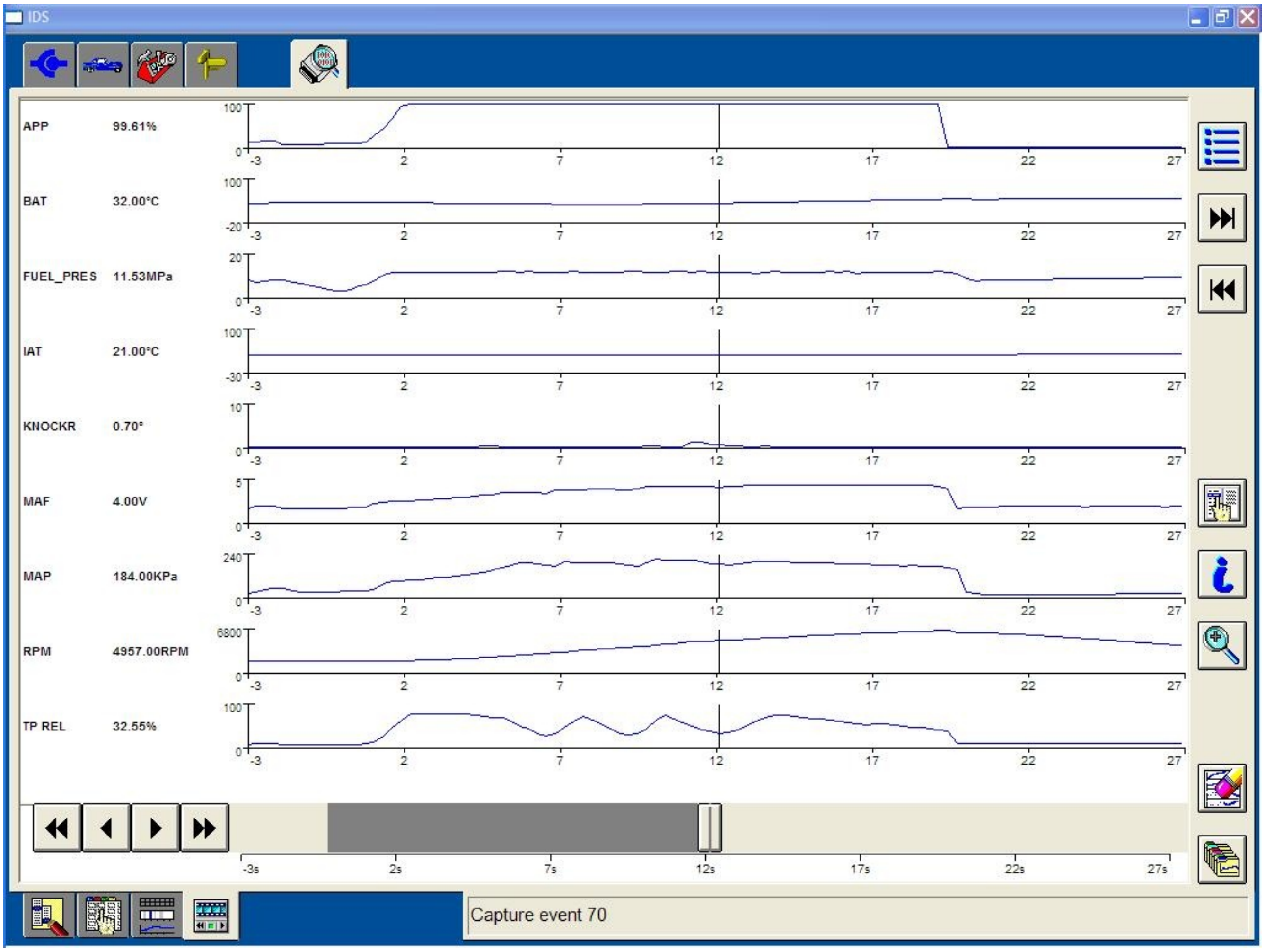
Each chassis dyno graph will be accompanied by a full datalog from the Ford/Mazda factory IDS datalogging system. This is the exact same datalogging/diagnosis systems used by every Mazda dealer in the U.S.A. We have also plotted various dyno graphs on top of each other so that we can more clearly demonstrate the exact power differences measured between these various calibrations.

FTCvA calibrations were tested to allow us to get a baseline of how the stock torque control system constantly manipulates the throttle position in order to control the torque output of the MS3 engine.



IDS Datalog of FTCvA

Many of you are familiar with what the datalogs of what the factory throttle control system does in order to maintain a certain amount of torque. This datalog is from a stock calibration and clearly demonstrates what many of you know. We have mentioned how we try to make our calibrations safer, you will want to notice the lengthy report of Knock Retard being removed from the engine during this dyno run. You can know use this information as a baseline that we can compare the remaining datalogs to.



IDS Datalog of FTCvB

This calibrations was programmed to cycle between full throttle duty cycle and 25% of full duty cycle (75% less duty cycle) starting at 3000 RPM. As you can clearly see the on the top data line, the Accelerator Pedal Position (APP), or gas pedal is clearly depressed and held at full throttle during the entire run. The TP REL, or throttle blade cycles between full duty cycle and 25% of full duty cycle. The dynograph of that dyno run is below and you can clearly see the corresponding effects of this calibration.

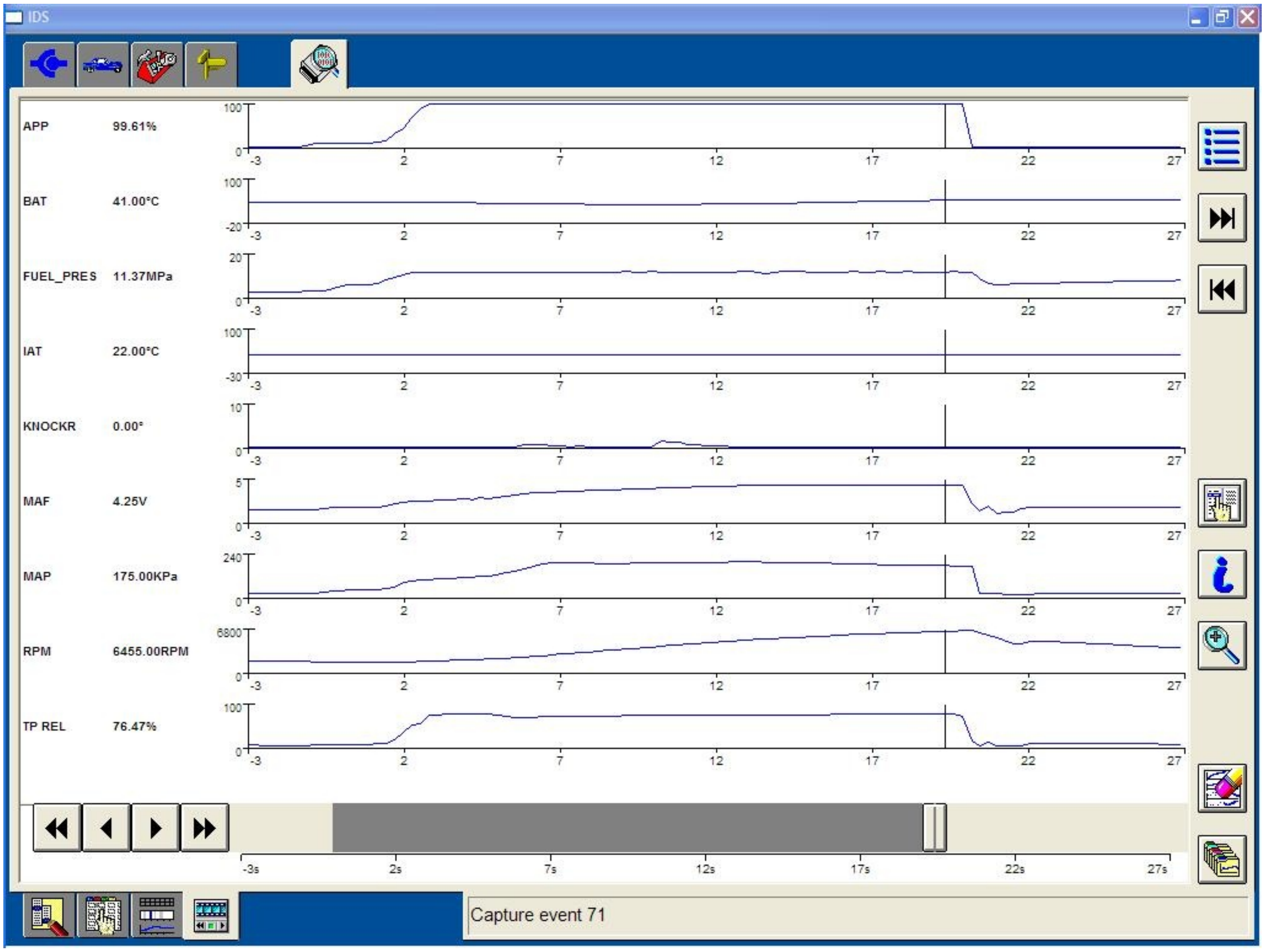
Dyno Graph of FTCvB

You can clearly see how the reduction of throttle duty cycle throughout the power band shows up as dips in torque across the entire RPM range. Please feel free to view the short video that we filmed while completing this testing = Link to come as soon as we get it uploaded.

Interesting Comparison

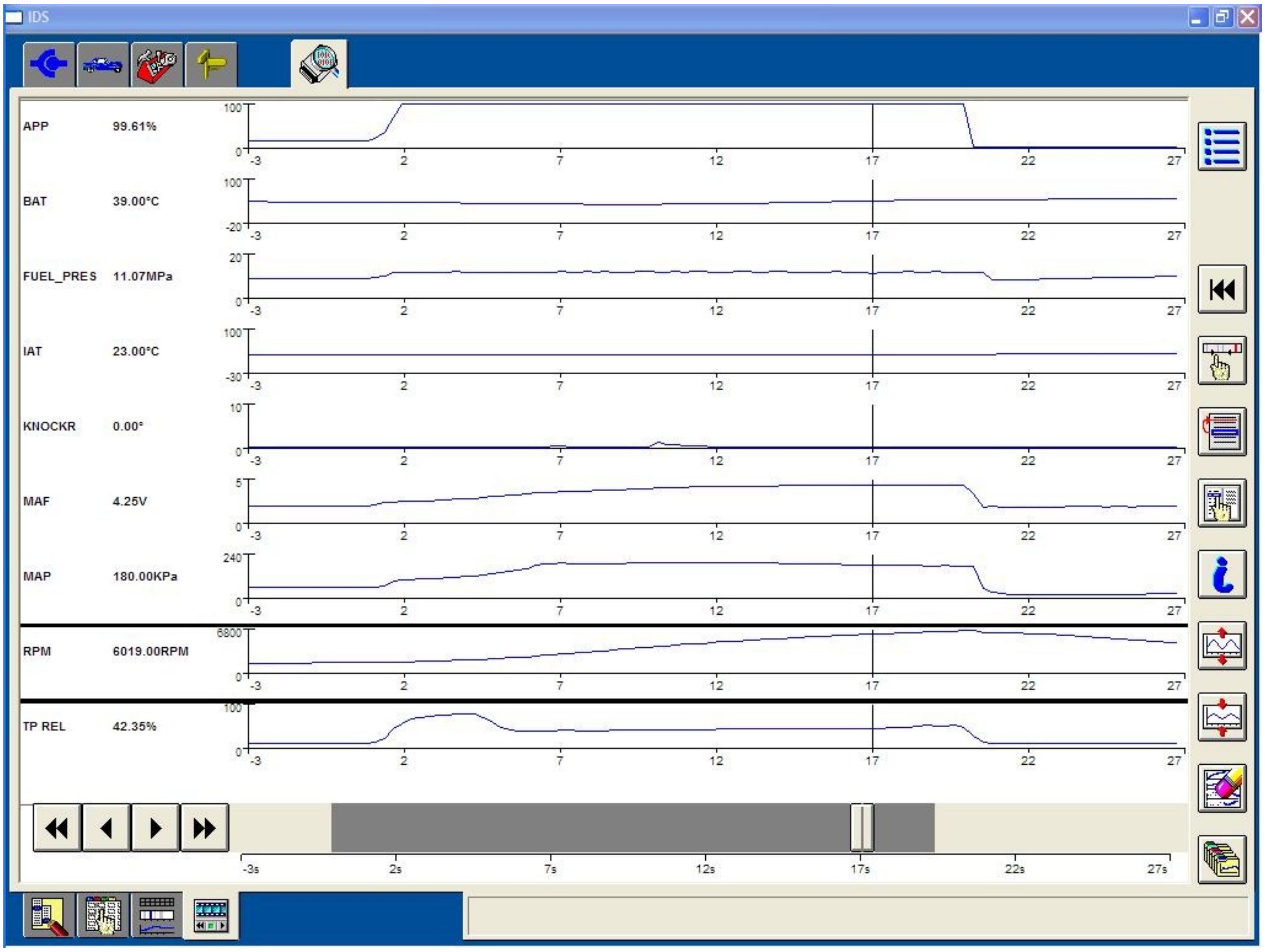
Dyno Graph of FTCvC

This calibration forces the throttle system to maintain full throttle duty cycle all the way to redline. We have composed a short video demonstrating these testing procedures. This video can be seem from this link.



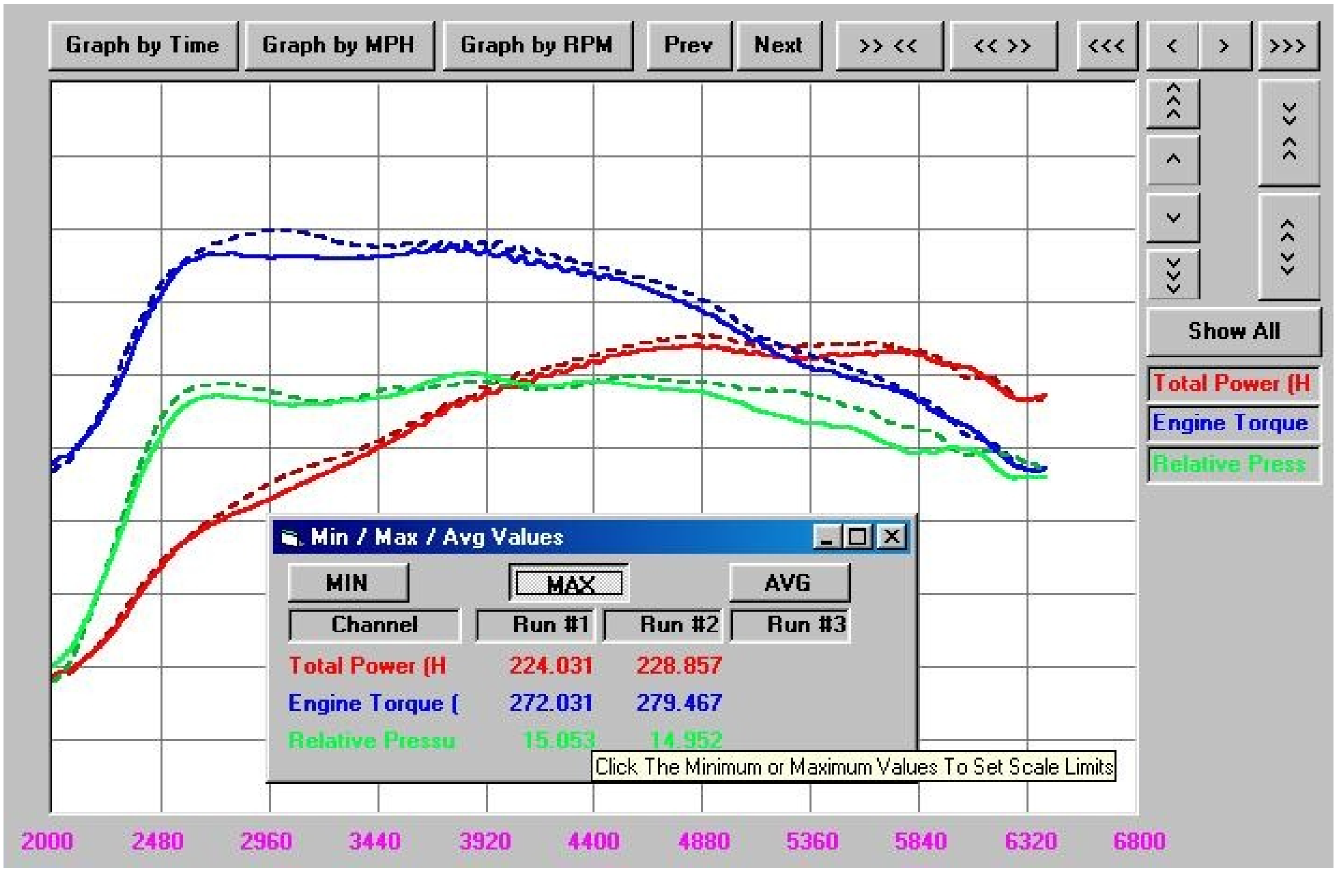
IDS Datalog of FTCvC

This calibration was programmed to hold full duty cycle all the way to engine redline. You can clearly see the TP REL signal mimics the APP signal with full duty cycle and holds the throttle wide open during the entire run. The only time the TP REL signal decreases is when the APP signal decreases.



IDS Datalog of FTCvD

This calibration was programmed to hold 50% of full duty cycle all the way to engine redline. You can clearly see the TP REL signal mimics the APP signal and holds the throttle wide open during the entire run, although the duty cycle run to the DBW throttle body is 50% of full throttle duty cycle. The only time the TP REL signal decreases is when the APP signal decreases. Next is a dyno graph comparing WOT power between the 100% full throttle duty cycles and 50% full throttle duty cycles. The results are very interesting.



In conclusion, we hope this information clearly demonstrates that Cobb Tuning has full control of the throttle mapping for the MS3. We too found it interesting that running the DBW assembly at 50% of full throttle duty cycles made a nominal power difference when compared to a calibration that runs 100% of full throttle duty cycles all the way to redline. This should benefit the community by several means, no we can focus our resources on providing the community with what it wants, and throughout this process we should be able to educate ourselves and the MS3 community about the varying improvement that can be made to these vehicle so that they can be enjoyed for time to come.

The vast majority of MS3 owners are not likely to invest thousands of dollars on top of the price of the vehicle in order to gain additional performance. We want to make sure that we do what we can to make these vehicles more enjoyable. For those that choose to modify their MS3 beyond this point, we have clearly proven that we have full control of the stock MS3 Engine Management System and we will be happy to help you achieve your goals. Please feel free to communicate your desires with us and we will do what can to make these vehicles more enjoyable as long as the dependability of these vehicles is not compromised.

Q: Does Cobb Tuning have full control of the throttle system on the MS3?
A: Yes.

Q: Does running the throttle system on full throttle duty cycle all the way to redline increase the power output of the MS3 engine?
A: Our test results so us that holding full throttle duty cycles all the way to redline does not increase the power output of the USDM MS3 engine. This does not mean that holding the throttle at full duty cycle with vehicles that have drastically different turbos, intake manifolds, heads, camshafts, exhaust manifolds will not be of benefit.

Q: Is the programmed throttle closing a detriment to the power output of the MS3 engine?
A: Our test results demonstrate that the peak power output of the MS3 is not significantly different even when a 50% of full throttle duty cycle is driving the DBW throttle assembly.

Q: Is the closing of the throttle prior to the engine redline the main reason for the drop-off in

engine torque production?

A: Our testing has concluded that this behavior is not the main reason why engine torque production drops off significantly as the engine RPM approaches redline. The ability for this engine to breath well in the higher RPM ranges is most likely limited to:

Turbocharger Mass Flow Capabilities
Camshaft Design
Exhaust Manifold Design
Head Mass Flow Capabilities