Flyin' Miata

tech line: 1 970 242 3800

Flyin' Miata piggy back ECU installation & tuning instructions for '99 through '04 Miatas

Revision 2.0

Contents

Section 1: Introduction 3
Required tools 3
Section 2: ECU installation 4
Section 3: O2 Signal Modifier and A/F Meter 9
Section 4: Required Knowledge 12
Section 5: Chip Installation Instructions 13
Section 6: Introduction to the Keypad 14
Section 7: Setting Up the ECU for Your Car 15
Section 8: Boost Controls 17
Section 9: Advanced Tuning 20
Tuning with a wide band O2 sensor 20
Ignition timing 20
Section 10: Table 1 Defaults 22
Section 11: Table 2 Defaults 23
Section 12: Definition of Zones 24
Section 13: Operation warnings 27

Section 1: Introduction

The Flyin' Miata piggy back ECU drives four auxiliary fuel injectors and provides tunable ignition retard based on a 16 column and 6 row map of engine RPM and manifold pressure. The ECU also provides turbo boost pressure control. A hand-held keypad in the cockpit allows adjusting of all the operating parameters.

We have made the piggy back installation as easy as possible by using plug-in connections where ever possible. However, some wires will still need to be cut and spliced at the ECU. On 2001 through 2003 cars, the wires going to the ignition coils need to be cut and spliced as well, in order for the Link piggy back to intercept the ignition signal.

For the wire splicing called for in this manual we recommend, and include, heat shrinkable crimp connectors. A crimp connection is better both structurally and electrically than a solder connection. If you do not believe us, try to find one soldered connection in the entire wire harness in your Miata. The integrity of a crimp connection depends on the quality of the tools used for the installation. Go to Sears and invest in a high quality pair of wire crimping pliers. These can be bought for $25 to $30 and will quickly pay for themselves in this and future projects.

The included crimp connectors use a heat shrinkable coating. Once the wires are crimped in place, heat the connector with a heat gun (buy one of these at Sears with your crimping tool) to shrink down the outer covering. This will provide a water tight seal for the life of your car.

Required tools

Every project on your Miata presents the opportunity to purchase more tools. Below are the tools you will need for the successful installation of this ECU.

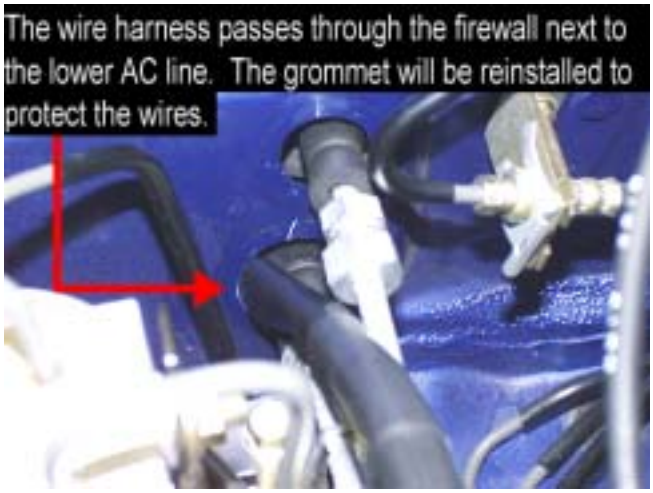
metric open/box wrenches
metric socket set
assorted slot and phillips screw drivers
metric allen wrenches
utility knife
wire crimp tool
wire strippers
heat gun

Section 2: ECU installation

1) Disconnect the negative battery terminal.

2) Inside the car remove the glove box by firmly pulling on the right side of the box to disengage the hinge. Also, remove the metal plate under the steering column by removing the two screws at the very bottom and gently pulling down on it.

One end of the harness included with the piggyback ECU has 9 metal terminals, one on each wire. On the other end of the harness, all the wires are pre-terminated with the appropriate connectors for their associated function. This harness will go through the firewall alongside of the lower AC line.

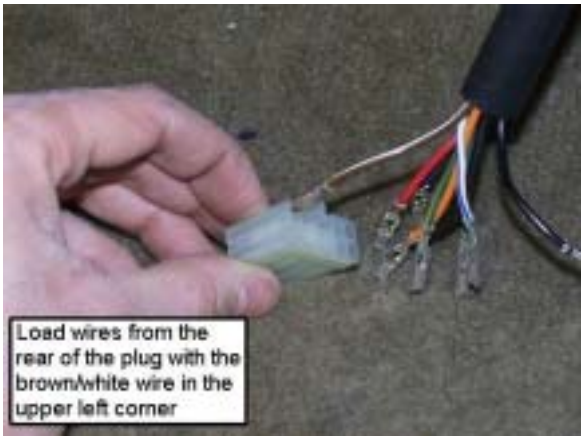


3) With a sharp knife, cut the rubber grommet around the lower AC line and remove it.

4) Cover the end of the harness with the 9 metal connectors with a piece of plastic secured with a zip tie. Run this end of the harness through the space around the AC line.

5) Pull at least 20” of wire though the firewall to reach the floor inside the car. This will allow enough wire under the hood for all the connections and still give you plenty of wire to work with inside the car.

6) Remove the empty plastic connector from the plug on the ECU. All the wires must be loaded into the plastic connector. Use the diagram on the next page for the position of the wires. The diagram refers to the wire colors when **viewed from the wire side of the plug with the tap on top**. Refer to the photo on the right, the brown/white wire will

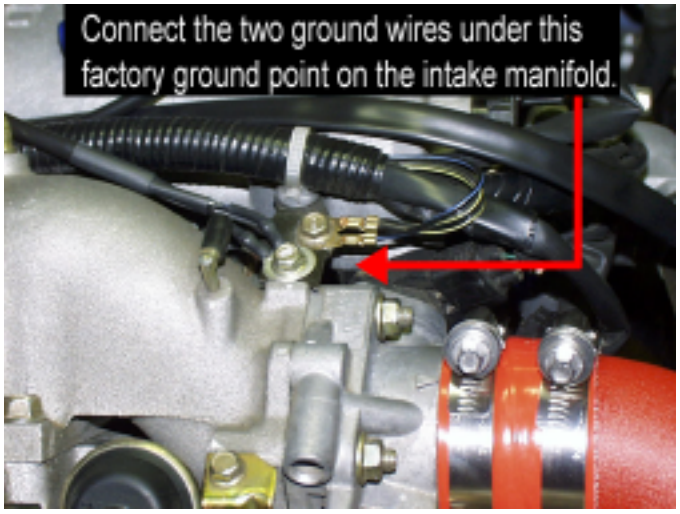


		TAB		
Brown/ White	Thick Black		Green	White/ Blue
Orange	Blue	Green/ Yellow	Red	Thin Black

Wire positions in the wire harness for the piggy back ECU

be in the upper left corner.

In the engine bay there will be 4 wire bundles with connectors on the ends. They are run through the engine bay as follows.

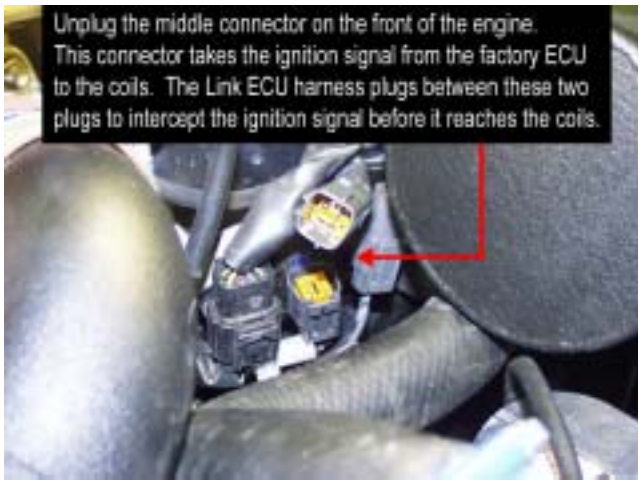


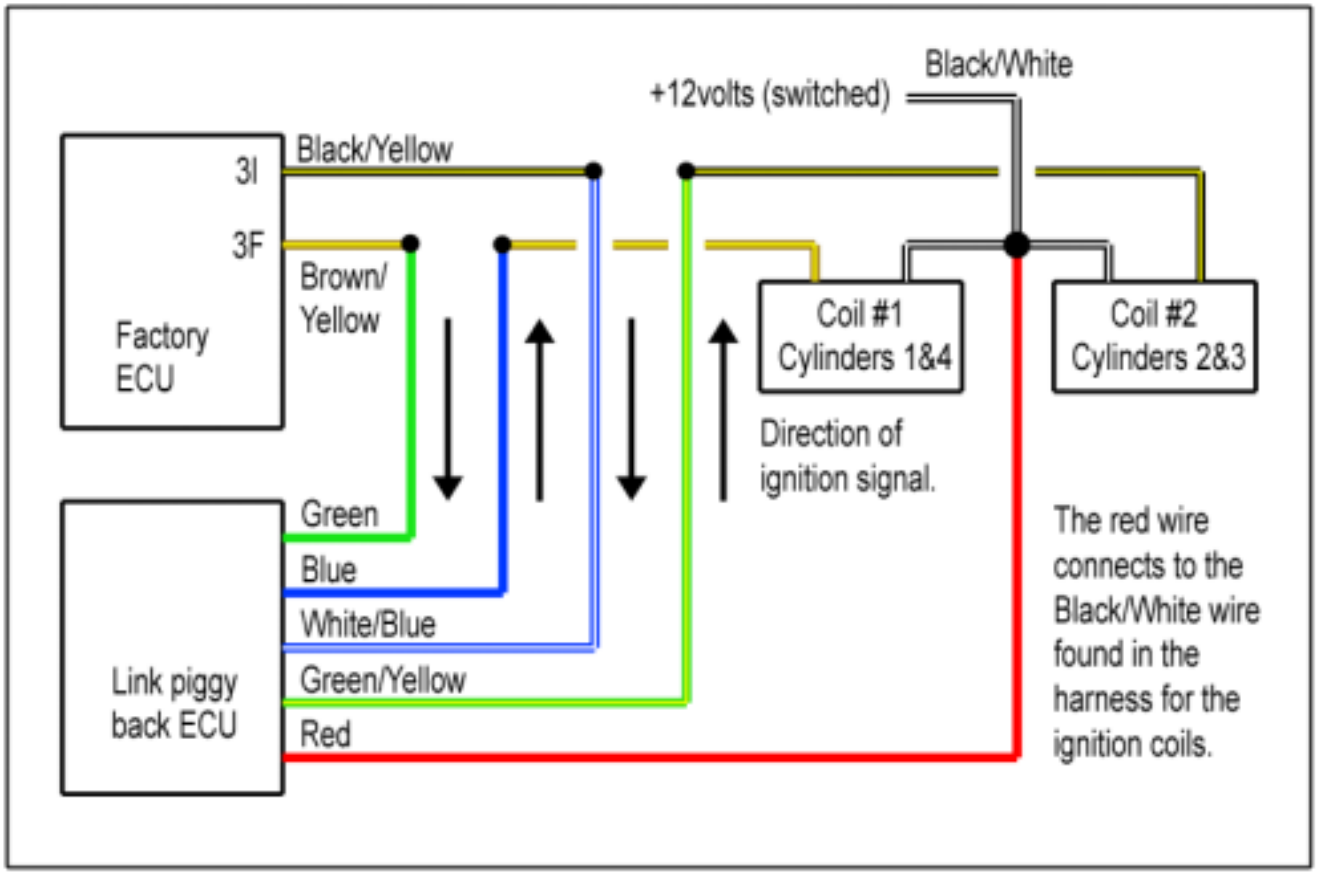
7) Run the two black wires with ring terminals on the end and the wires with the grey plastic connectors down along the factory wire harness bundle between the cam cover and the intake manifold.

8) The two black wires with ring terminals are ground wires for the ECU. At the front of the motor, connect both ring terminals under the bolt for the ground connection at the throttle body.

NOTE: On '99 & '00 cars perform step 9 and skip steps 10 through 14. On '01 through '04 cars skip step 9 and perform steps 10 through 14.

9) **On '99 and '00 cars** there is a gray four wire connector on the front of the timing cover, pull the two halves apart and plug the gray connectors on the new harness in between them. This is where the Link ECU intercepts the factory ignition signal.





10) **On ’01 to ’04 cars** the ignition system was changed to a coil-on-plug design. We will need to tap into the factory wire harness for the ignition signals on top of the cam cover. The wire diagram is shown above.

Note: To access the wires called for from the Link ECU, cut the two grey plugs off the harness as shown in the photo to the right.

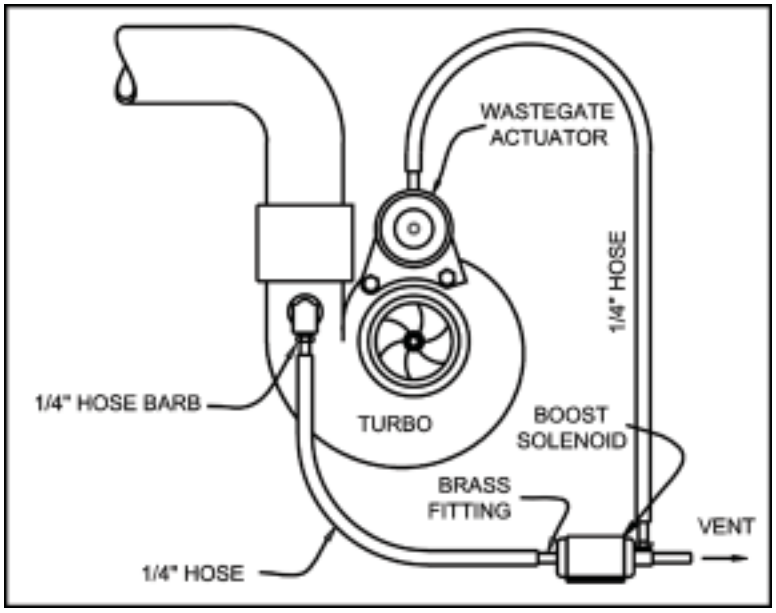
11) **On ’01 to ’04 cars** the factory ECU drives the number one coil with a brown/ yellow wire. Cut the brown/yellow wire. Using the red butt connectors, connect the green wire to the ECU end of the brown/yellow wire and the blue wire to the coil end of the brown/yellow wire.

12) **On ‘01 to ‘04 cars** the factory ECU drives the number two coil with a black/yellow wire. Cut the black/yellow wire. Using the red butt connectors connect the white/blue wire to the ECU end of the black/yellow wire and the green/yellow wire to the coil end of the black/yellow wire.

13) **On ‘01 to ‘04 cars** connect the red wire from the Link harness to the black/white wire in the car’s harness with the quick splice connector supplied. This will provide 12 volts for the Link ECU to operate. Do not cut the black/white wire, just tap into it.

14) The white connector with red and orange wires is for the auxiliary fuel injectors. Run this pair along the passenger side fender and connect it to the harness on the fuel injectors. Connect each leg of the fuel injector harness to each fuel injector.

15) Run the red and brown/white wires, for the boost control solenoid, across to the driver’s side of the engine bay along the steel line for the brake vacuum booster. If this installation is not using the Link’s boost control feature, simply tuck the pair of wires for the boost control solenoid out of the way. They will not be used.



16) On FM2 turbo installations, mount the boost control solenoid to the rear of the baffle around the intake air filter using a 6mm bolt through the hole in the baffle. Plug the wires into the harness run along the firewall in the previous step.

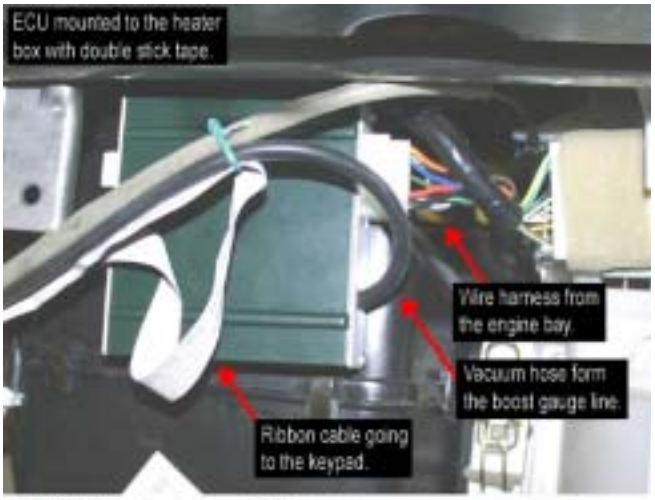
17) The boost control solenoid needs a pressure signal source after the turbo. On our FM2 turbo kits a 1/4” hose barb is mounted on the turbo for this purpose. Use the 1/4" hose, supplied in bag 13A, to connect to the brass fitting on the solenoid.

18) Connect the black plastic fitting at the opposite end of the solenoid, pointing at a right angle to the brass fitting, to the wastegate actuator on the turbo. The second plastic fitting pointing straight out the end of the solenoid vents to atmosphere. Leave it open.

19) Secure the connections of the hoses with wire ties. If these hoses blow off, control of the wastegate will be lost and the turbo will make enough boost to damage the engine.

20) Take the piggy back ECU into the passenger side of the car. Plug the wire harness, the ribbon cable, and the vacuum hose into the ECU.

21) Mount the Link ECU behind the glove box. On ‘99 &’00 cars the rear of the AC box provides a large flat space to locate the ECU



'99 & '00 Mount the ECU to the rear of the heater box.

with double-sided tape, as shown in the photo to the right. On ‘01 and later cars slip the ECU between the AC box and the AC fan housing.

‘01-’03 Mount the ECU to the side of the heater box.

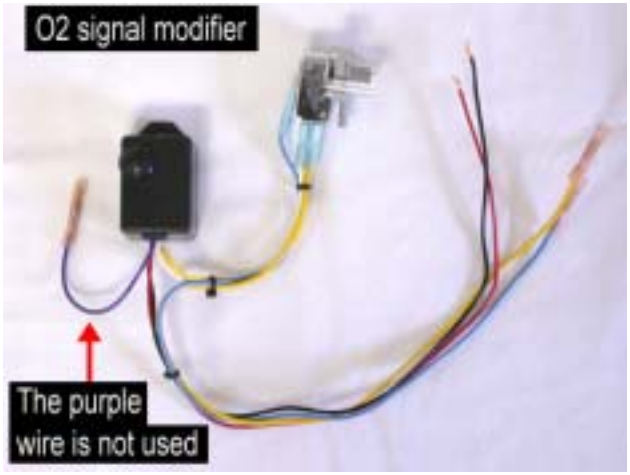
Section 3: O2 Signal Modifier and A/F Meter

The O2 signal modifier is a small device that intercepts the factory O2 sensor signal before the factory ECU. It sends a conditioned signal to the ECU when the motor operates in boost to keep the factory ECU from “seeing” the additional fuel necessary under boost. An air/fuel (A/F) meter is also included to monitor the air fuel ratio when operating under boost.

The metal panel under the steering column and the glove box should still be removed from the last section. The factory ECU is located under the dash board on the driver’s side of the car right above the clutch pedal. Standing on your head to work on the car will be necessary for this section. Use the supplied electrical connectors to connect the A/F meter and the O2 signal modifier as follows. Refer to the diagrams on pages 10 &11 for the wire connections and the identification of the ECU terminals to be used.

O2 Signal Modifier:

1) Remove the three harness plugs from the ECU and cut off some of the electrical tape around the wires. This will allow you to separate them and access the individual wires needed for this operation.



2) The first wire we are interested in is the blue wire in terminal A. This is the front O2 sensor signal wire. Cut the wire about two inches out from the ECU connector and strip ¼” of insulation off both ends.

3) Crimp the blue wire on the O2 signal modifier to the ECU end of the cut blue wire in Terminal A using the supplied butt connector.

4) Crimp the yellow wire from the O2 signal modifier to the O2 sensor end of the blue wire in terminal A using the supplied butt connector.

5) Connect the red wire from the O2 signal modifier to the white/red wire in terminal B using the supplied quick splice connector.

6) Connect the black wire from the O2 signal modifier to the black/red wire in terminal C using the supplied quick splice connector.

7) The pressure switch on the O2 signal modifier needs a pressure signal from the intake manifold. Use the “T” fitting to tap into the vacuum hose in to the signal line run through the fire wall for the boost gauge.

8) If the Lambda Link A/F meter is not being used, jump to step 13.

Lambda Link A/F meter:

It is convenient to store the A/F meter in the glove box when not using it. If you wish to do this, run the wires from the glove box area over to the driver's side of the car behind the dash.

9) Connect the white wire from the A/F meter to the yellow wire from the O2 signal modifier using the supplied quick splice connector.

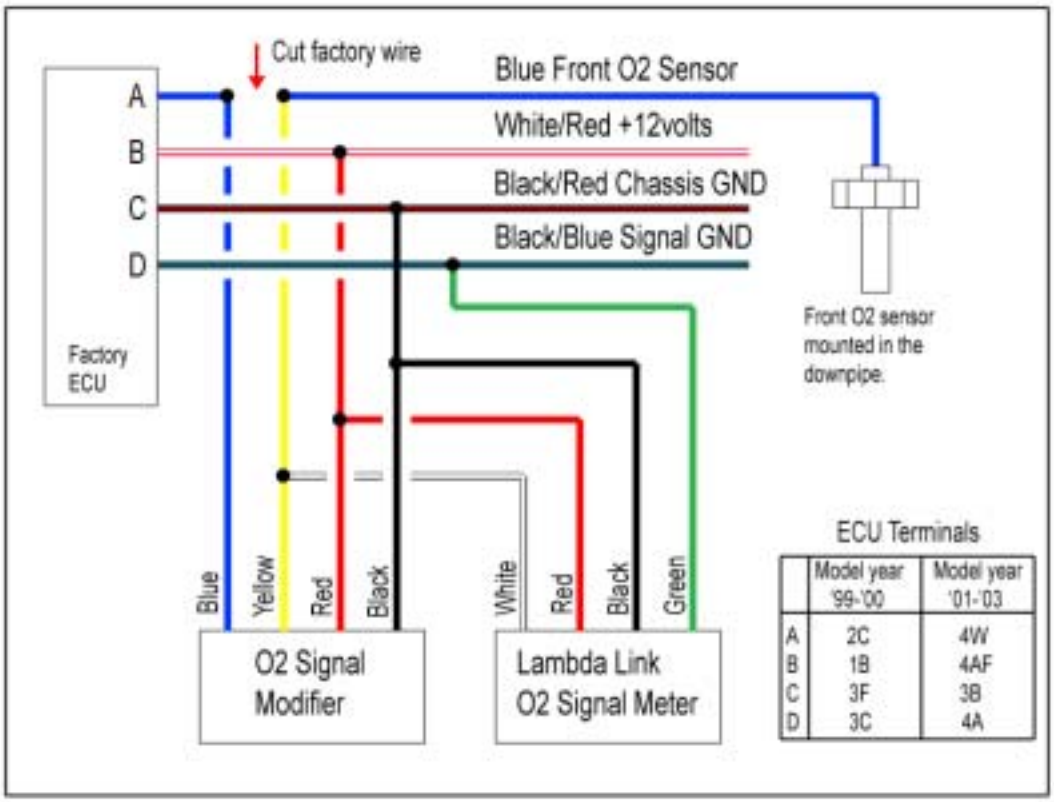
10) Connect the red wire from the A/F meter to the red wire on the O2 signal modifier using the supplied quick splice connector.

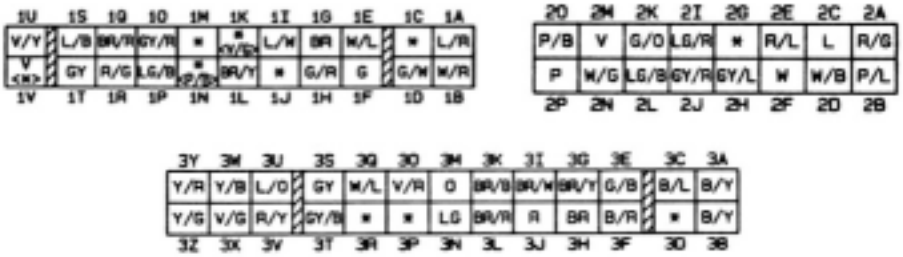
11) Connect the black wire from the A/F meter to the black wire on the O2 signal modifier using the supplied quick splice connector.

12) Connect the green wire from the A/F meter to the black/blue wire in terminal D using the supplied quick splice connector.

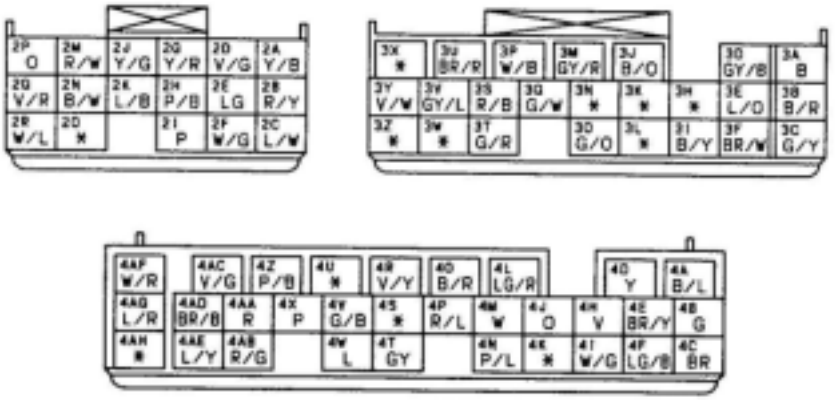
13) Use the tape on the back of the O2 signal modifier box to attach it to the side of the ECU case. Zip tie the switch to a nearby wire harness and plug the ECU connectors back into the ECU.

14) Reinstall the glove box.





ECU harness plugs for ‘99 & ’00 Miatas viewed from the harness side with the tap on top.



ECU harness plugs for ‘01-’03 Miatas viewed from the wire side with the tabs on top.

Section 4: Required Knowledge

The Flyin' Miata piggy back ECU is pre-programmed from Flyin' Miata so that minimal tuning time is needed to get the car up and running. Reading and following sections 6,7, & 8 are required to get the car running. Section 11 offers detailed information about all of the parameters the ECU controls and should answer any questions that arise about the operation of the piggy back ECU.

Important things to know about the FM piggy back ECU:

1) The Flyin' Miata piggyback ECU activates when the engine operates above a user adjustable manifold pressure, normally atmospheric pressure, 0 psi on the boost gauge. At this point the ECU fires four auxiliary fuel injectors, intercepts and delays the ignition signal, and controls the turbo boost pressure. All these functions are user programmable with a hand-held key pad included with the system.

2) The piggy back ECU uses an on-board MAP (Manifold Absolute Pressure) sensor to measure the intake manifold pressure.

3) The ECU uses memory locations called "zones" for all its operating parameters. Tables of all the zones with their default values can be found in sections 9 & 10. Commonly used zones are listed in the main menu, accessible with the hand held keypad, with a descriptive title. All zones can be accessed from the EDIT Z menu found at the end of the menu list using the keypad.

4) The ECU includes 2 different default settings to get the car up and running quickly. One for turbocharged (Table 2) and one for supercharged (Table 1) applications.

5) The ECU measures pressure in kilo Pascals (kPa) with approximately 100 kPa equaling atmospheric pressure at sea level. The ECU measures temperatures in degrees Centigrade.

6) To make understanding the manual easy, memory locations displayed in the main menu on the keypad are shown in red. Memory locations not displayed in the main menu are in blue and can only be modified from the EDIT Z menu.

Section 5: Chip Installation Instructions

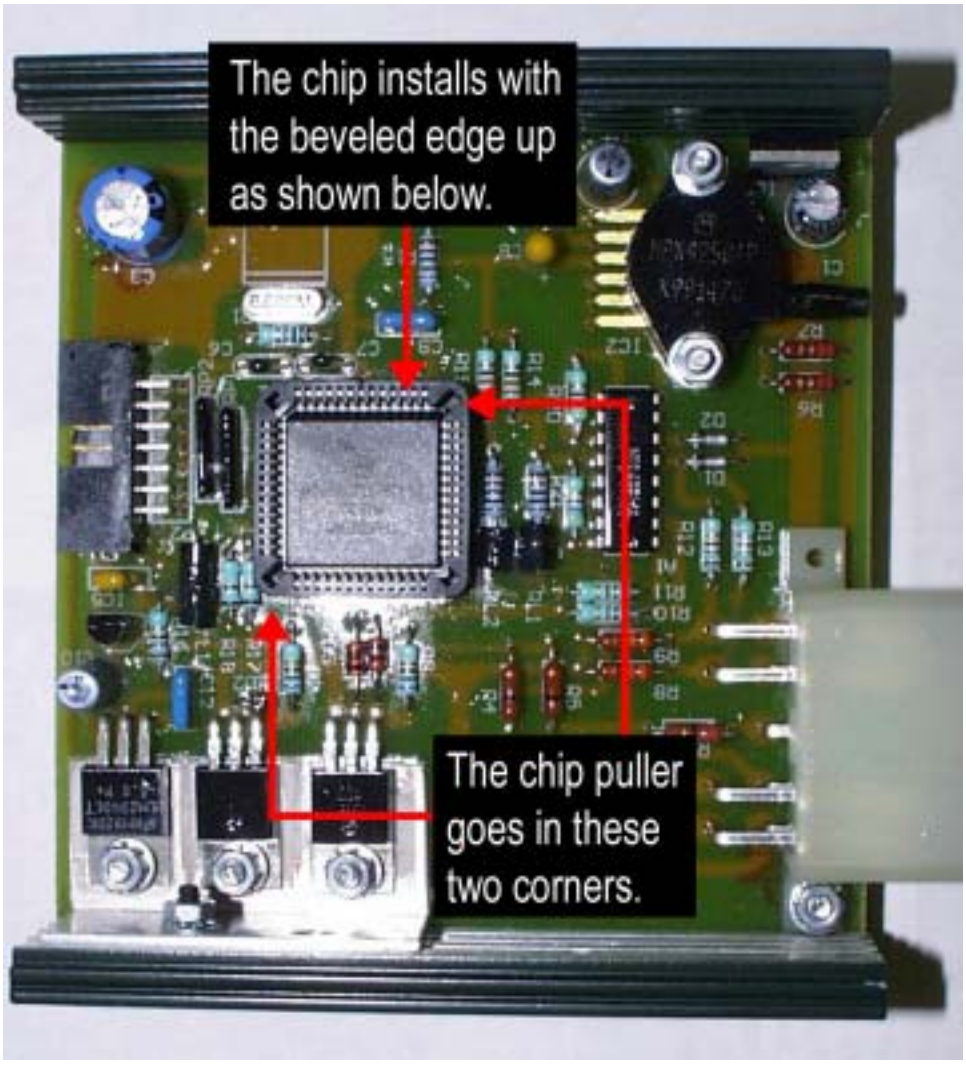
Note: When installing a new ECU for the first time, skip this section. The microprocessor has already been installed before the ECU was shipped. This procedure only applies when upgrading to new software after the ECU has been installed.

To remove the microprocessor a chip puller must be used. Using paperclips, etc. to try to remove the chip will probably damage the chip or socket. Radio Shack sells a 52-pin PLCC puller for less than $5. Buy one.

The microprocessor can be found in the picture of the circuit board below. Insert the two prongs of the puller into the openings in the corners of the socket and squeeze the puller. The chip will pop out.

After removing the old chip with the proper puller, install the new chip by pressing it into place firmly with your thumb. The chip must be properly oriented. If you look very closely at the edges of the chip, you will see that one edge is beveled and has a small dot in the middle of the edge. This is the top of the chip. With the multiplug on the printed circuit board at the bottom right corner, the top of the chip should be up.

Once the chip is in place, replace the cover on the ECU case and go to the next section of the manual.



Section 6: Introduction to the Keypad

The keypad included with the system is the only way to see and alter the settings. There are three pairs of keys:

The SELECT keys move through the main menu. When turning on the car, the ECU always wakes up in the RPM screen. This is considered the beginning of the main menu. Use the up and down keys to scroll through the menu choices. When it gets to the end of the main menu (where it says "EDIT Z0 XX"), it will stop.

Once the desired screen has been found, changes are made to the setting by using the ADJUST keys. Some screens don't have any adjustable parameters in them, they are read only. The ADJUST keys are used to access additional information in some of these screens, for instance in the RPM screen, pressing the ADJUST down key accesses the current manifold pressure (MAP).

The EDIT menu is a submenu of less often used parameters. It is accessed by holding the SELECT up key until it stops. At this point, the screen will display "EDIT Z0 XX". You move through this menu by using the EDIT up and down keys. To make changes, use the ADJUST keys, just like in the main menu.

Storing: When ever a change is made in the ECU it must be stored or the change will be lost when the car is turned off. There are two ways to store information. Storing will only occur at idle. First is in the STORE screen. In this screen press both ADJUST keys until the screen fills with asterisks, then release the ADJUST keys. The second way to store is in the EDIT Z menu. In any screen in the EDIT Z menu press both EDIT keys and the screen will fill with asterisks signaling that the new information is being saved. In both cases, the keys to initiate the save function can be released as soon as the asterisks appear.

Section 7: Setting Up the ECU for Your Car

1) **Load Default values:** The ECU contains 2 sets of default values to help speed along the tuning process. Turn the car "on" but do not start the engine. Scroll to the screen that displays RELOAD TABLE 1. Table 1 is for supercharged cars and Table 2 is for turbocharged cars. Press the adjust down key to switch to Table 2 for turbocharged cars.

2) Press the select up key once to go to the RELOAD screen. Here, press and hold both adjust keys until the screen fills with asterisks, then release the adjust keys. This loads the default settings into the ECU.

3) **Check MAP SENSOR operation:** In the RPM screen press the adjust down key on the keypad to display the MAP sensor reading. At sea level the MAP reading should be about 100kPa. Higher elevations will read lower values. The MAP sensor has an accuracy window of +/-5kPa. Refer to the table below for the atmospheric pressure at different elevations.

Elevation (ftX1000)	0	1	2	3	4	5	6	7	8	9
Pressure (kPa)	100	97	94	91	87	84	80	77	74	71

4) **Set ONSET:** Go to the ONSET screen and set it to 100kPa using the adjust keys. This sets the piggyback to start making is fuel and timing changes at 0 on the boost gauge. Below ONSET the car operates completely on the stock ECU and fuel injectors.

5) **Set the boost target:** Go to the BOOST screen and set it to 100kPa. This will limit the boost to the value set by the mechanical wastegate controller on the turbo or the external waste gate. This will be about 6psi on an FM2 turbo kit. Setting the ECU up to raise the boost pressure will be covered in the next section.

6) Store these changes.

7) Start the car and check for fuel leaks around the junction of the auxiliary fuel injectors with the fuel rail.

8) **Check the vacuum signal:** Go to ONSET screen and check the number in parentheses. This measurement is the vacuum in the intake manifold at idle. The reading should be steady between 25kPa and 35kPa. If you do not have a reliable map signal, nothing in the ECU will work correctly.

> **Note:** The fuel numbers loaded into memory have been developed on our Dynojet chassis dynamometer with a wide band O2 sensor. These are more accurate than what can be obtained from the air/fuel meter supplied with the kit, using the stock O2 sensor in the car. These values have proven to work well for boost values up to 12psi. Therefore, we do not recommend changing them unless tuning is being performed with a wide band O2 sensor.

9) **Test Drive:** Go for a drive with the top and windows up. The boost will be set by the mechanical wastegate actuator on the turbo to around 6psi. Drive gently at first to make sure

everything is OK. Accelerate gently into boost. Watch the boost gauge and verify that the boost builds to about 6psi and no more. If the boost exceeds 8psi let off the throttle immediately and check the hose routing on the boost control solenoid.

10) When accelerating into boost, listen for engine knock. At this boost pressure knock should not be a problem. If knock is heard repeat the process while monitoring the key pad in the ZONEIGN screen. Note what zone the knocks occurred in, then go to that ignition zone in the EDIT Z menu, and raise the number by one point. Repeat this process until no knocks are heard

Note: For the next two steps use the table below to identify normal operation of the engine as seen by the Lambda Link air/fuel (A/F) ratio meter.

Throttle Position	Manifold Pressure	Lambda Link Display
Steady	Vacuum	Dithering or Off
Moving down slowly	Vacuum	Off, Red or Yellow
Moving down quickly	Vacuum to boost	Yellow or 1st Green
Steady	Boost (5psi to 7psi)	2nd Green
Steady	Boost (8psi to 9psi)	3rd Green
Moving up quickly	High vacuum	Off

Note: For the next two steps, values only accessible in the EDIT Z menu may have to be adjusted. To locate the desired zones refer to the default tables in sections 10 & 11 or the list of memory locations in Section 12

11) **Verify the fuel enrichment:** All readings to verify fuel enrichment during this step must be taken with the accelerator pedal in a steady state. If the accelerator pedal is moving down acceleration fuel will be added by the ECU and will color the readings. When operating in the 300 row, 0psi on the boost gauge, the A/F meter should be operating in the yellow and/or the first green LEDs. The reading may bounce around a bit, but that is not a problem. If the right most green LED lights up at 0psi on the boost gauge, go to the EDIT Z menu and remove 5 points of fuel out of each zone from Zf300 to Zf375. Don't forget to save these new fuel values. If the fuel mixture is still reading too rich, repeat this step a second time. If a second reduction in row 3 fuel does not produce the desired results, call the tech line at FM for further instruction.

12) **Accelerator pump:** Before testing the accelerator pump functions, change the following values in the EDIT Z menu. Z16=10, Z17=15, Z18=14, Z19=11, Z20=4. These values have been determined since the defaults have be set into the software included in the piggy back ECU.

The accelerator pump feature is triggered by the change in manifold pressure. It is possible to open the throttle slowly enough to not trigger the acceleration fuel. When testing the acceleration fuel, open the throttle quickly. If you see the air/fuel ratio go lean as the throttle goes down, then come back to normal, add more fuel to the corresponding acceleration zone. If the A/F ratio stays rich, but dips lean before stabilizing, then lengthen the acceleration decay time.

Section 8: Boost Controls

The turbo boost pressure is controlled by a part called a wastegate. The wastegate gets its name from the fact that it “wastes” a portion of the exhaust gas by diverting it around the turbine wheel to limit the speed of the compressor wheel, and hence the boost pressure. Wastegates can either be integral or external. All FM2 turbo systems use an integral wastegate, while the old FM3 system and the current FM4 use an external wastegate.

On the FM2 turbos, a gold colored can, called the wastegate actuator, is mounted on top of the turbo with a rod that connects to a lever on the wastegate. The wastegate actuator houses a diaphragm and a spring calibrated to give the turbo a certain amount of boost. All turbo systems have to produce a minimum level of boost. No turbo system can run zero boost pressure. This manual refers to this minimum level of boost as mechanical boost. The Link piggy back ECU can only increase the boost level above mechanical boost. When the ECU’s boost target is set to 100kPa the ECU does not control the boost and the engine will operate at mechanical boost.

Without the Link piggy back ECU, the wastegate actuator would have a hose connecting one side of the diaphragm to the pressurized air coming out of the compressor called the signal hose. This hose allows the wastegate actuator to “see” the level of boost developed by the turbo. The Link piggy back ECU intercepts this signal with the boost control solenoid and manipulates this pressurized air signal to control boost pressure. The solenoid bleeds off some of the pressurized air so that the wastegate actuator “sees” a lower level of boost than what the turbo actually makes. The amount of bleed off is called duty cycle. The ECU controls boost pressure by altering the duty cycle of the wastegate solenoid. Understanding this concept is crucial in understanding how the ECU controls boost pressure.

The Link piggy back ECU uses closed loop boost control. This means the ECU modulates the solenoid at a given duty cycle, then checks the boost pressure to see if that position produces the desired boost pressure. If the wastegate duty cycle produces the wrong boost level the ECU will alter the duty cycle to correct the boost level.

Zones used for boost control
Boost control in the Link piggy back ECU uses the following zones to control the boost pressure. Knowledge of these zones is vital for getting the boost set accurately. The descriptions are an abbreviated version of the full descriptions found in Section 12.

BOOST (map): The boost pressure target that the ECU will maintain.

WG BASE: The value of wastegate duty cycle that achieves the desired boost level.

WG RPM: The RPM point at which the ECU goes into closed loop mode to maintain the boost target. WG RPM should be set at the minimum RPM value that the car physically can produce the target boost.

WG SENS: The speed at which the ECU will make changes to the wastegate setting to maintain the desired boost level. We have good experience with settings between 2 and 7 with 5

being optimal. Lower numbers slow the changes and slow spool up while higher numbers make the ECU respond faster at the expense of overshoot.

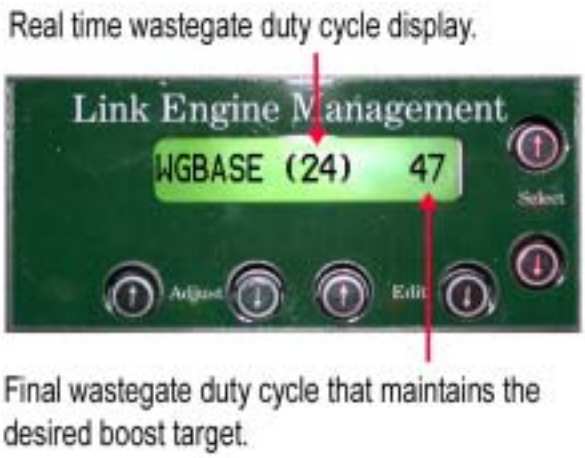
WG MAX DUTY: An adjustable upper limit for the wastegate duty cycle to prevent over boost conditions.

1) **Set the boost target:** Once you are comfortable with the car's performance at 6psi, go to the BOOST screen and raise the boost target to your desired setting using the adjust keys. We strongly recommend 160kPa (9psi).

2) Go to the WG BASE screen and lower the setting on the right to 25 using the adjust keys.

3) Go to the MAX WG DUTY screen and raise the setting to 80. This screen is a safety feature. At this point we are raising it out of the way until the boost control parameters are set correctly.

4) Store these new values.



5) **Set WGBASE:** We need to find the value of duty cycle that gives the desired boost pressure. Drive the car in 3rd gear at 2500RPM. Accelerate at full throttle up to 5000RPM and have your co-pilot watch the WG BASE screen. The number in parentheses will increase and then stabilize as the target boost setting is reached. Enter this stabilized value in the right side of the WG BASE screen using the adjust keys. Repeat this process until the number in parentheses settles out to the same number on the right side. Once this value is found the boost should stabilize at the boost target.

6) **Set WG MAX DUTY:** Once the final value of WG BASE is found set WG MAX DUTY 1 point higher than WG BASE.

7) **Set WGRPM:** On the highway in top gear, apply full throttle starting at 2500RPM. Take note at what engine RPM the turbo makes full boost. Enter this value into WG RPM.

WG RPM has a very powerful affect on the boost control system. If it is set too

low, the ECU will go closed loop before the motor can make full boost because there is not enough energy in the exhaust to spin up the turbo to full boost, but the ECU does not know this. In this case, the ECU will close down the wastegate to make the boost target. When the engine does reach the point at which it can make full boost the duty cycle will be too far way from the desired value and the boost pressure will overshoot.

If WG RPM is set too high the ECU will go closed loop too late. The boost pressure will hang at 6psi (the setting of the wastegate actuator) then slowly climb up to the boost target.

Note: Since WG BASE and WG RPM are affected by each other, WG BASE might have to be altered a point or two after WG RPM is set to achieve smoother boost control.

8) If the boost wavers around the boost target, lower WG SENS a point or two. We have found 5 to work well. Increasing WG SENS will help the boost rise faster at the expense of overshoot and oscillation.

9) Once the boost controls are working well, save all the changes by going to STORE and pressing both adjust keys until the screen fills with asterisks.

10) Since the manifold pressure is now higher than before you will need to check again for knock. Accelerate while in the ZONE IGN screen and note the zone of any knock that is heard. Go to that ignition zone and raise the number by one point. Do not forget to store the changes.

11) At this point the ECU is tuned. The keypad can be stored in the glove compartment.

Section 9: Advanced Tuning

As stated in section 7, the default fuel values are good for making power and are safe from knock for most users. However, there are plenty of variables that could allow a particular car, or set up, to make more power with fuel tuning beyond the defaults. More precise fuel tuning for a particular car can be achieved by using a wide band O2 sensor mounted in the car.

Tuning with a wide band O2 sensor
Ideally, fuel tuning should be performed with a wide band O2 (WBO2) sensor because of its greater accuracy over wider Air/Fuel (A/F) ratios and Exhaust Gas Temperatures (EGT). One way of tuning the fuel is to use a chassis dyno with a WBO2 sensor. The Dyno will record the A/F during a full throttle run. After the run, the fuel numbers in the Zf table can be altered to address any rich or lean spots. Because the fuel zones interpolate between each other, fuel tuning is best performed at the pressure center of each row. Below is a table showing the centers of each row and the desired A/F ratio.

Row	400	500	600
Center	140kPA	180kPa	220kPa
Desired A/F	12.5:1	12.0:1	11.5:1

> **Note:** WBO2 sensors must be located in the downpipe before the catalytic converter. Current downpipes used in Flyin' Miata turbo kits have a second O2 sensor fitting welded into the pipe before the catalytic converter just for mounting a WBO2 sensor. You are welcome. Do not try to tune a car with a WBO2 sensor after the catalytic converter because the cat removes the gasses we are trying to measure.

In the past, WBO2 sensors cost several thousand dollars and required electronic packages to run them properly. In the last few years their proliferation into OEM applications has lowered their prices to a few hundred dollars. A WBO2 sensor still requires its own stand-alone electronics package to function, but a WBO2 sensor is now within the ability of the average enthusiast to install in a car.

Flyin' Miata sells a WBO2 unit that easily mounts in the Miata and provides a very accurate signal. The output of this unit can be connected to the A/F ratio gauge included in the turbo kit. Fuel can be tuned on the road by making full throttle runs and having a co-pilot monitor the A/F ratio as the car sweeps through the RPM range.

To use a WBO2 sensor connected to the Lambda Link A/F meter included in the kit, follow the wire diagram on page 10. However, do not connect the white wire from the Lambda Link to the yellow wire. Instead, connect the white wire on the Lambda Link to the white wire on the AEM WBO2 sensor. All the other connections will remain the same because the factory ECU will run on the stock O2 sensor.

Ignition timing
The ignition zones in the piggy back store the amount of timing retard, in degrees, that the piggy back ECU removes from the factory timing curve based on the manifold pressure and

engine RPM. The default values are safe from knock in most cases. However, with the use of 93 or 94 octane fuel the ignition retard numbers can be reduced to gain more power. In fact, when operating under boost, reducing the amount of ignition retard gives the largest power gain.

The shape of the ignition timing retard curve is a bell with the peak value at the motor's torque peak, between 4000RPM and 5000RPM. To make more power the height of the peak will be lowered. Make one degree reductions at a time in order to lower this peak. The piggy back ECU does not have a knock sensor so knock will need to be listened for by the driver and/or passenger. Keep the top and windows up when making these changes so that knock can be heard. Knock sounds like a hand full of nuts and bolts in a coffee can being shaken violently. The timing can be reduced as much as the user wants as long as knock is not heard.

Warning: Reducing Ignition retard too far causes knock. Knock can break pistons and rods. Reduce the ignition retard in one degree steps and listen closely for knock.

Section 10: Table 1 Defaults

	MASTER		TPS	TPS	NO.	WASTEGATE					RPM				
ONSET	FUEL		LOW	HIGH	CYL.	RPM	BASE	SENSE		MODE	LIMIT				
110	10	40	0	70	4	33	48	5	1	1	72	0	0	0	0
Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15

ACCELERATION				ACCEL	MAX										
0-2K	2K-4K	4K-6K	6K-8K	DECAY	DUTY										
28	28	28	26	4	60	0	0	0	0	0	0	0	0	0	0
Z16	Z17	Z18	Z19	Z20	Z21	Z22	Z23	Z24	Z25	Z26	Z27	Z28	Z29	Z30	Z31

Fuel Zones

kPa	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Zf100	Zf105	Zf110	Zf115	Zf120	Zf125	Zf130	Zf135	Zf140	Zf145	Zf150	Zf155	Zf160	Zf165	Zf170	Zf175
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	Zf200	Zf205	Zf210	Zf215	Zf220	Zf225	Zf230	Zf235	Zf240	Zf245	Zf250	Zf255	Zf260	Zf265	Zf270	Zf275
	0	0	40	44	62	62	62	52	34	34	30	30	30	30	30	30
120	Zf300	Zf305	Zf310	Zf315	Zf320	Zf325	Zf330	Zf335	Zf340	Zf345	Zf350	Zf355	Zf360	Zf365	Zf370	Zf375
	0	50	58	58	55	56	72	67	65	74	66	80	78	58	59	54
160	Zf400	Zf405	Zf410	Zf415	Zf420	Zf425	Zf430	Zf435	Zf440	Zf445	Zf450	Zf455	Zf460	Zf465	Zf470	Zf475
	50	50	64	64	61	62	78	73	71	80	72	86	84	64	65	60
200	Zf500	Zf505	Zf510	Zf515	Zf520	Zf525	Zf530	Zf535	Zf540	Zf545	Zf550	Zf555	Zf560	Zf565	Zf570	Zf575
	50	50	70	70	67	68	84	79	77	86	78	92	90	70	71	66
254	Zf600	Zf605	Zf610	Zf615	Zf620	Zf625	Zf630	Zf635	Zf640	Zf645	Zf650	Zf655	Zf660	Zf665	Zf670	Zf675

Ignition Zones (degrees of ignition retard)

kPa	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Zi100	Zi105	Zi110	Zi115	Zi120	Zi125	Zi130	Zi135	Zi140	Zi145	Zi150	Zi155	Zi160	Zi165	Zi170	Zi175
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	Zi200	Zi205	Zi210	Zi215	Zi220	Zi225	Zi230	Zi235	Zi240	Zi245	Zi250	Zi255	Zi260	Zi265	Zi270	Zi275
	0	0	0	0	1	1	4	4	4	4	3	2	0	0	0	0
120	Zi300	Zi305	Zi310	Zi315	Zi320	Zi325	Zi330	Zi335	Zi340	Zi345	Zi350	Zi355	Zi360	Zi365	Zi370	Zi375
	0	0	0	1	2	4	6	7	7	7	7	7	6	5	5	5
160	Zi400	Zi405	Zi410	Zi415	Zi420	Zi425	Zi430	Zi435	Zi440	Zi445	Zi450	Zi455	Zi460	Zi465	Zi470	Zi475
	0	0	0	2	4	8	9	9	10	10	9	8	7	6	6	6
200	Zi500	Zi505	Zi510	Zi515	Zi520	Zi525	Zi530	Zi535	Zi540	Zi545	Zi550	Zi555	Zi560	Zi565	Zi570	Zi575
	0	0	0	2	4	8	12	14	14	14	14	14	12	10	10	10
254	Zi600	Zi605	Zi610	Zi615	Zi620	Zi625	Zi630	Zi635	Zi640	Zi645	Zi650	Zi655	Zi660	Zi665	Zi670	Zi675

Boost Targets

0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z700	Z705	Z710	Z715	Z720	Z725	Z730	Z735	Z740	Z745	Z750	Z755	Z760	Z765	Z770	Z775

Section 11: Table 2 Defaults

	MASTER		TPS	TPS	NO.	WASTEGATE					RPM				
ONSET	FUEL		LOW	HIGH	CYL.	RPM	BASE	SENSE		MODE	LIMIT				
110	9	40	0	70	4	32	36	5	1	0	72	0	0	0	0
Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15

ACCELERATION				ACCEL	MAX										
0-2K	2K-4K	4K-6K	6K-8K	DECAY	DUTY										
28	28	28	26	4	60	0	0	0	0	0	0	0	0	0	0
Z16	Z17	Z18	Z19	Z20	Z21	Z22	Z23	Z24	Z25	Z26	Z27	Z28	Z29	Z30	Z31

Fuel Zones

kPa	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
40	0 Zf100	0 Zf105	0 Zf110	0 Zf115	0 Zf120	0 Zf125	0 Zf130	0 Zf135	0 Zf140	0 Zf145	0 Zf150	0 Zf155	0 Zf160	0 Zf165	0 Zf170	0 Zf175
80	0 Zf200	0 Zf205	0 Zf210	0 Zf215	0 Zf220	0 Zf225	0 Zf230	0 Zf235	0 Zf240	0 Zf245	0 Zf250	0 Zf255	0 Zf260	0 Zf265	0 Zf270	0 Zf275
120	0 Zf300	0 Zf305	50 Zf310	55 Zf315	58 Zf320	57 Zf325	54 Zf330	47 Zf335	37 Zf340	32 Zf345	27 Zf350	27 Zf355	27 Zf360	27 Zf365	27 Zf370	27 Zf375
160	0 Zf400	50 Zf405	59 Zf410	59 Zf415	60 Zf420	61 Zf425	67 Zf430	72 Zf435	74 Zf440	73 Zf445	71 Zf450	68 Zf455	62 Zf460	54 Zf465	50 Zf470	50 Zf475
200	59 Zf500	59 Zf505	59 Zf510	59 Zf515	61 Zf520	62 Zf525	69 Zf530	77 Zf535	80 Zf540	79 Zf545	78 Zf550	72 Zf555	65 Zf560	56 Zf565	50 Zf570	50 Zf575
254	69 Zf600	69 Zf605	69 Zf610	69 Zf615	69 Zf620	71 Zf625	76 Zf630	82 Zf635	84 Zf640	84 Zf645	81 Zf650	81 Zf655	71 Zf660	62 Zf665	56 Zf670	54 Zf675

Ignition Zones (degrees of ignition retard)

kPa	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
40	0 Zi100	0 Zi105	0 Zi110	0 Zi115	0 Zi120	0 Zi125	0 Zi130	0 Zi135	0 Zi140	0 Zi145	0 Zi150	0 Zi155	0 Zi160	0 Zi165	0 Zi170	0 Zi175
80	0 Zi200	0 Zi205	0 Zi210	0 Zi215	0 Zi220	0 Zi225	0 Zi230	0 Zi235	0 Zi240	0 Zi245	0 Zi250	0 Zi255	0 Zi260	0 Zi265	0 Zi270	0 Zi275
120	0 Zi300	0 Zi305	0 Zi310	0 Zi315	0 Zi320	1 Zi325	2 Zi330	2 Zi335	3 Zi340	2 Zi345	1 Zi350	1 Zi355	0 Zi360	0 Zi365	0 Zi370	0 Zi375
160	0 Zi400	0 Zi405	0 Zi410	0 Zi415	0 Zi420	1 Zi425	4 Zi430	6 Zi435	8 Zi440	7 Zi445	7 Zi450	6 Zi455	4 Zi460	3 Zi465	3 Zi470	3 Zi475
200	0 Zi500	0 Zi505	0 Zi510	0 Zi515	0 Zi520	2 Zi525	5 Zi530	9 Zi535	10 Zi540	12 Zi545	12 Zi550	11 Zi555	10 Zi560	9 Zi565	9 Zi570	9 Zi575
254	0 Zi600	0 Zi605	0 Zi610	0 Zi615	0 Zi620	4 Zi625	8 Zi630	16 Zi635	20 Zi640	20 Zi645	21 Zi650	19 Zi655	18 Zi660	17 Zi665	17 Zi670	17 Zi675

Boost Targets

0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Z700	Z705	Z710	Z715	Z720	Z725	Z730	Z735	Z740	Z745	Z750	Z755	Z760	Z765	Z770	Z775

Section 12: Definition of Zones

TEST RPM xxxx: This displays the current engine RPM. Pressing the adjust down key displays the manifold pressure (MAP). Pressing the edit up key will display the software release code.

CYLINDERS (4): (Z5) Tells the ECU how many cylinders the engine has. This obviously needs to be set to 4.

ONSET (map): (Z0) Sets the MAP value at which the piggy back ECU starts adding fuel. Set this value to 100kPa.

RPM LIMIT 7200: (Z11) Sets the rev limit for the additional fuel injectors. Fuel cut off occurs at this set point. This setting does not affect the factory ECU's rev limit.

MASTER FUEL: (Z1) Controls the overall fuel delivery to the engine. The range is from 5 to 30 with higher numbers delivering more fuel. MASTER FUEL moves all fuel zones simultaneously. Start tuning with the default value. We have found it to work very well. Change it only if you find a majority of the fuel zones above 80% or below 20% to achieve the correct air/fuel ratio.

FUEL ZONES: (Zf100 to Zf675) These zones represent a grid, 6 rows by 16 columns, of fuel correction values used to fine tune the operation of the engine. The grids are shown in sections 9 & 10. The first digit of the zone number indicates the manifold pressure row. The second and third digits indicate RPM column. Example: Zf430 would mean "row 4" (low boost), between 3000 and 3,500 RPM (30). Rows are divided by manifold pressure as follows: The columns are divided by engine RPM, 0-8000 in 500RPM steps. Keep in mind that only zones above the ONSET value will have any affect on the operation.

ROW	RANGE	CENTER
1	0-40	20
2	41-80	60
3	81-120	100
4	121-160	140
5	161-200	180
6	201-254	227

Manifold pressure ranges and zone centers. Units are kPa.

ACCEL Z=0: (Z16-Z19) Simulates the accelerator pump on a carburetor by increasing the amount of fuel upon sudden throttle opening. The zones affect the following RPM ranges:

Z16: 0 to 2000 RPM
Z17: 2001 to 4000 RPM
Z18: 4001 to 6000 RPM
Z19: 6001 to 8000 RPM

ACCEL DECAY: (Z20) Controls the decay time of the accelerator pump fuel. Lower numbers

offer faster decay. The value of accel decay is not in seconds.

IGNITION ZONES: (Zi100 to Zi675) The same grid used for fuel values, but for ignition retard values. These timing numbers will be subtracted from the ignition timing set by the factory ECU. If knock occurs, the number in the corresponding ignition zone must be raised to increase the amount of retard in that zone.

STORE: The ECU works like a PC. Any information changed in the memory while the car operates must be saved before turning the car off. Scroll to the screen that says STORE and press both adjust keys down together until the screen fills with asterisks, then release. Once the asterisks are gone, all the new information is saved into permanent memory. The ECU will not store above idle speed. A store can also be done anywhere in the EDIT Z menu by holding both edit keys down until a row of asterisks fill the screen. Once values are stored in memory the only way to loose them is to write something else on top of them. Removing the battery will not cause the information to be lost.

INJ / MAP: This is a read-only function which displays the actual auxiliary fuel injector duty-cycle as a percentage of maximum. E.g. 28% indicates that the injectors are flowing 28% of their maximum volume. The MAP display shows the current manifold air pressure (MAP) value.

WG MAX DUTY: (Z21) An adjustable upper limit for the wastegate duty cycle to prevent over boost conditions. This should be set one point higher than the WG BASE value required to hold the boost target. For example, if WG BASE is set to 45, WG MAX DUTY should be set to 46.

BOOST (map): (Z700 to Z775) Manifold pressure targets when allowing the Link piggy back ECU to control the boost pressure through the boost control solenoid. The zones are separated in 500RPM increments from zero to 7500RPM. When a value is entered in the BOOST screen all zones from 700 to 775 are filled with the same value. If a boost curve is desired, different target values can be entered into each zone in the EDIT Z menu.

Making adjustments in the BOOST screen in the main menu will add or subtract the change to all the individual targets. For example, if Z730 is sent to 160 and Z735 is set to 170 and the value in the BOOST window is changed to 200 then Z730 will change to 190 and Z735 will change to 200.

WG RPM: (Z6) The RPM point at which the ECU goes into closed loop boost control, attempting to hit its boost target zones. WG RPM should be set at the minimum RPM value that the car physically can produce the target boost.

WG BASE: (Z7) Used to tell the ECU the wastegate duty cycle required to achieve the boost target. The ECU uses this value while the turbo is spooling up by holding the wastegate close the final value. This speeds up spoolup without overshooting the boost target.

WG SENS: (Z8) The ECU uses a closed loop (feedback) system to control the boost setting. The optimum sensitivity level will be a compromise between quick spool up and boost target

stability. High sensitivity values produce quick spool up at the expense of overshoot and oscillation around the target boost value. Low sensitivity values slow the spool up while protecting against overshoot. Experience has shown that values between 2 and 7 produce good results.

RELOAD TABLE (1 or 2): The microcontroller has two data tables stored in its memory. Table 1 has defaults for supercharged applications and Table 2 has defaults for turbo set-ups both using our 4-injector intake manifold. Use the adjust keys to choose between the two tables.

RELOAD: Used during the initial setup to transfer the default data table to the ECU's permanent memory. RELOAD fills the ECU memory with the default settings from either Table 1 or Table 2. Press both adjust keys down together and hold until the screen fills with asterisks, then release. This will overwrite all values stored in memory.

EDIT: Enables the zone editor function, which allows access to all zones for viewing and editing. The EDIT function may be used at any time, with or without the engine running. Use the edit keys to select the appropriate zone(s) and the adjust keys to change the selected zone. The zones are identified by a number which may be correlated to its function by consulting the tables in sections 10 & 11. Fuel zones and ignition zones are identified by an "f" or "i" respectively to discriminate between fuel and ignition values. Storing of edited values may be done by pressing both edit keys together until display shows a row of asterisks and then releasing. This method of storing works only when in the Edit menu. Alternatively, STORE may be selected and used as normal.

MODE: (Z10) This number corresponds to 8 different bit flag settings. They have no user functions, so please do not change these.

Section 13: Operation warnings

Fitting the Flyin' Miata ECU to your car will increase performance. In the case of a turbo charged installation, the power output from the motor is more than doubled. An increase like this requires the driver to use good judgment when tuning and operating the car.

1) Always use the highest octane fuel available.

2) If you hear knock from the motor, lift off the throttle immediately. The forces from knock are the most damaging to an engine.

3) On turbocharged cars, keep an eye on the boost gauge. If you see the boost pressure exceeding your target boost level lift off the accelerator pedal. Miatas can incur serious engine damage when exposed to boost pressures over 15psi.

4) Be kind to your transmission and differential. The stock transmission and differential have proven reliable in turbo charged cars provided "mechanical empathy" is exercised. This means no smoky burnouts from a standing stop and no "speed shifting".