Preface

A lot of information is available regarding Electronic Fuel Injection (EFI) systems. This information allows us to piece together a picture of what an EFI system is, how it accomplishes the aim, and provides us with the information to better understand the 1985/1986 Honda Gold Wing Computerized Fuel Injection (CFI) system. The information in this document is not unique to any specific EFI system, but can be used as a reference for earlier electronic ignition systems and even the older points/condenser systems.

I am not the author of this information, but I am a messenger. I have searched the internet, read several EFI system books, perused the Original Equipment Manufacturer (OEM) service manuals for answers to my questions. This has allowed me to put together an understanding of the CFI system, and EFI systems in general.

The information herein is my understanding of what an EFI system is, what it can do, how it does it, the different interactions between the sensor inputs-outputs, what the terminology means and how everything rolls up and becomes an EFI system.

This document is one piece of the EFI puzzle for the upgrade-modification of the CFI system on my 1985 Honda GL1200 Gold Wing Limited Edition fuel injected (FI) model.

The more I search for information on various EFI issues and components, the more answers I am finding. My understanding improves every time, especially when I put together a new document regarding the EFI-CFI systems. A concept that I have read about on a specific forum or want to look for, suddenly makes sense.

The more I delve into the EFI world, the more design information and how the manufacturers have used this information is found. This information has changed my understanding of the EFI system. This design information provides an insight into the challenges that manufacturers have had to contend with, and what you may want to consider when considering, and/or proceeding with, an EFI project. It is nice to know how specific design considerations impact an EFI design, especially one you and I may be working on.

The EFI parameters that I am interested in continuously take me down various rabbit holes where I generally find additional information that may or may not be relevant. I like to include a Reader's Digest version of the information and a link, if possible, of where to find it.

It is not unusual to read a car, motorcycle or product internet forum, and look at the timeline to find that EFI projects have been ongoing for years. Life gets in the way, loss of interest, budget constraints and the likes all play a part in whether the project makes it to fruition or not.

Fuel injection has its roots in the diesel engine and air industries. WWII brought about significant advances in EFI systems specifically because of the need for planes to operate at higher altitudes – superchargers and turbo boost systems. Fighter planes required an alternative fueling system to carburetors because of the need to have the plane fly in different orientations depending on the nature of the flight. Mechanically operated fuel injection systems were the order of the day.

The carburetor has also succumbed to the emission standards demanded by environmental legislation, and are now very much relegated to the older vehicles, never to be resurrected for daily use by an OEM.

The EFI system has one purpose, to control the fuel delivery to the engine through the fuel injectors. There are many other components, but the fuel injector is the delivery component.

The 1985/1986 Honda Gold Wing CFI system was and still is, a state-of-art EFI system. It has all the components necessary for a modern day EFI system with a few notable exceptions that will be discussed.

The CFI system components are also used for Gold Wing EFI conversions. I submit that the Honda CFI system of the day could easily meet today's requirements and emission standards without too much modification.

There are a few additional sensors used today depending on the EFI system, but the one component that is a must have today, but was not needed back in the day, is the exhaust oxygen (O2) sensor. This O2 sensor was not used in this CFI system.

Delving into the EFI world can be a daunting and overwhelming experience, not for the faint of heart. This may be the case, but with all endeavours, nothing ventured, nothing gained.

EFI documentation is readily available, but most have the same information. This document will hopefully provide EFI information in small bite size chunks and finally, at the end, my version of the EFI puzzle will be complete.

I want my document to be different. I want it to incorporate the best of what I have found, the interrelationships between EFI system component parameters, why you should consider a specific engine tuning path, what the ECU tuning software parameters are and how each is affected by other parameters.

I wanted this to be a short intro into the EFI/CFI system, lessons learned, tuning aspects and steps involved, and finally getting to the road. Alas, this is not the case.

Without further procrastinating, let's enter the EFI world.

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Introduction

1985/1986 Honda Gold Wing GL1200 Computerized Fuel Injected Models – 19 June 2023

My reason for delving into the EFI world is because I own a 1985 Honda Gold Wing FI model. There are no mechanics or CFI technicians available to work on my 1985 Gold Wing so I have to be my own mechanic and CFI technician.

This early CFI system forms the basis for Honda's Programmable Fuel Injection (PGM-FI) system. Honda now calls the ECU equivalent a Powertrain Control Module (PCM) as it controls more than the engine.

These are easy motorcycles to work on and maintain mechanically. The CFI system is another story. It requires a fairly in depth understanding so that you don't go down the proverbial rabbit hole when engine issues arise. There is an assistant available, and that is the Engine/Electronic Control Unit (ECU). It has an on-board diagnostic program that continuously monitors the CFI system components and alerts you to any issues regarding these.

I have identified alternate components/parts for most of the CFI components/parts by perusing the internet and the various motorcycle forums.

There are two components of the CFI that I have not identified potential replacements for, specifically the CFI system ECU and spark units (coil drivers – ignition modules).

Finding a suitable alternative for the spark units will require instrumenting the CFI system spark units to determine how the spark units' work. This will provide the information needed to source a suitable alternative. You can also employ a trial-and-error process and through experimentation, come up with the aftermarket alternative.

The CFI system ECU is another story, and is more difficult to address. There is no design information available, you cannot reprogram this ECU, and it is an older technology.

If a circuit fails, the ECU is generally a throw away unit. To replace this CFI system ECU, you need to find another used, old CFI system ECU, and if you do, it may not be inexpensive.

Do not let my sentiments regarding a faulty CFI system ECU misguide you. This is a very complex, well-designed ECU, and has stood the test of time.

What are the options? I have mentioned the first option, replace with another used, old ECU. The second option is to investigate and install a new, aftermarket ECU.

Replacing the CFI system ECU is not as easy as it sounds. The CFI system ECU is a complex design, and can rival most of the aftermarket ECUs. The design and programming of this ECU if it were made available new today, would easily compete with some of the higher end, proprietary ECUs available.

I have briefly explained why I have delved into the EFI world. My second reason for this is that my 1985 Gold Wing is my long-term retirement project. This includes modifying and adding circuits/systems that interest me. Every change, or modification I have done has enhanced my riding enjoyment.

The last piece of this puzzle is ensuring the longevity of my 1985 Gold Wing; hence we come to the reason for this document, the replacement-upgrade of the CFI system ECU.

The CFI system has all the components installed that would be needed for an upgrade; it is an EFI system. The component data may not be available, but through experimentation and using typical norms for the various components, you can tune the new ECU to work with the existing CFI components.

You have the option to upgrade the CFI system components for more modern-day components, and use the data for these in the project. I have done this with some of the components, and systems that are used with the CFI system. One such system that I felt needed an upgrade is the fuel system.

The aftermarket ECU that I have chosen is the Speeduino ECU based on the Speeduino Project. It is an open-source ECU in that the operating program code is available for all to use and modify as required to suit the individual's needs.

To connect the new ECU microprocessor to the CFI system requires and interface board. The interface board that I am using is an original Speeduino interface board. There are a multitude of Speeduino compatible clone interface boards available for you to choose from.

The Speeduino interface board connects the microprocessor, an Arduino Mega 2560, to the CFI system.
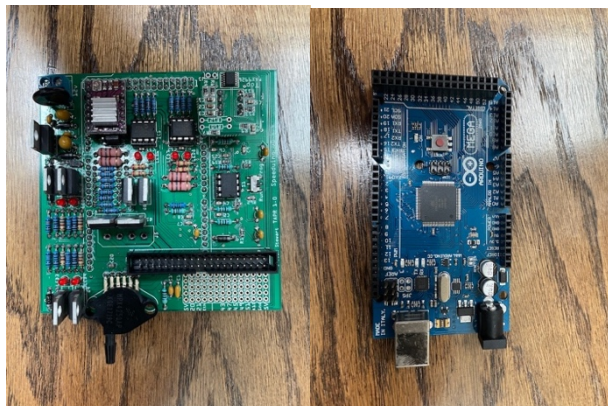
Speeduino Interface Board.   Microprocessor

The Speeduino ECU programming is evolving and still being developed. There is a goodly number of contributors to the source code, and because of this, some of the finer details/features of the higher end ECUs are being incorporated.

Another reason for choosing the Speeduino ECU is that should I be so inclined, I can develop my own requirement, add it to the source code I am using, test and trial it. Once this new aspect of programming is complete and proven to be effective for the feature being addressed, I can submit it for inclusion in the main source code.

Using this open-source aftermarket ECU does have limitations, but research indicates that with some forethought and a very good understanding of the ECU programming, you can possibly emulate a much more refined, and feature rich ECU.

The microprocessor for the Speeduino is the Arduino Mega 2650. The Arduino family of electronic components is widely used for many applications. There are a host of clones available for use because of the open-source code that is the backbone of the Arduino family.

The Speeduino ECU is comprised of two components, the interface board and the microprocessor. The interface board can be upgraded, or changed to a different type to suit future needs without changing the microprocessor, the Arduino Mega 2560.

The various interface boards, Speeduino or interface boards based on the Speeduino platform, come in different shapes and sizes, with various features/functions as needed to suit most everyone's needs. There are interface boards with a very small footprint depending on space available, or those that have more features that you may want to use in the future.

EFI system engine tuning is second nature to a lot of people, especially those who have been involved in the EFI world and with the Speeduino Project that I am using. It is not intuitive, and it requires research to put the pieces together. There are no EFI tuning or dyno shops on Vancouver Island, same for available people available to assist with an EFI project.

Engine tuning is not a black art. It is a skillset that can be learned and utilized effectively. To become proficient at engine tuning and the sequence in which to progress, a lot of time needs to be spent learning this skill, and trying to determine the various steps to be taken and the order in which these should be done.

I am a consummate investigator and want to know what I am dealing with. This is a good way to be, but can be a hindrance when trying to move forward. There has been a lot of recommendations and assistance on the Speeduino and other forums that if I had understood the issue at the time, this project would have progressed faster. Not having an EFI system mentor close by means I have to be my own engine tuning specialist. I have to take the recommendations and suggestions, understand what is being presented, and understand how these relate to EFI system tuning.

Electronic Fuel Injection Overview

In the book by Matt Cramer and Jerry Hoffman – "Performance Fuel Injection Systems", there is a brief discussion on EFI tuning myths. One of these myths is that an aftermarket ECU will not operate the engine as well as a factory model.

This may be the case depending on how much time and effort you want to put into learning about the intricacies of an EFI system, the relationship between the various EFI parameters, and tuning the engine with the new ECU. You can imagine without too much effort where this sentiment comes from.

You are not constrained by the same requirements as an OEM, but depending on the vehicle use, you should try to maintain the same standard as an OEM.

OEMs spend countless hours and considerable funds to meet its societal and government requirements regarding emission standards and such. You need to try and accomplish as many of these goals as possible within your budget and resources.

Budget and time, especially time, are generally the Achilles heel when dealing with an EFI project. You need to have a good understanding of what you are embarking on, and very realistic goals.

Electronic Fuel Injection (EFI)

A discussion regarding an EFI system can be as in depth or lightly glossed over as you wish. I have spent hours browsing the internet and the various forums – motorcycle and car/truck, for information, general and specific, about the EFI system and components.

This section will deal with the CFI system components that I will be using primarily because these components are already installed. There are some components that are being changed to better utilize the new ECU.

An EFI system is a computer-controlled fuel delivery system that reliably and accurately delivers the required fuel to the engine to mix with the air mass flowing into the engine to provide the proper Air Fuel Ratio (AFR) for optimal engine operation.

This is accomplished through the use of an ECU that receives sensor inputs from the various components that make up the EFI system. The ECU determines how much fuel is required to be delivered to the engine through the fuel injectors to have the correct air-fuel mixture for combustion from these sensor inputs.

EFI systems are not a group of cookie cutter systems that are all the same. Each OEM has a specific set of design requirements that allow its EFI system to operate well without breaking the bank so to speak.

There are many considerations. Component design specification(s), the type, style, and size of the various components, how and where in the engine system is the fuel to be delivered are part of the EFI equation.
Most of us will never question the engine operating system as long as when we want to ride, the motorcycle starts and off we go.

The OEM bases its design, and the installation of that design, on a cost benefit basis. The OEM purchases the components for its EFI system such as fuel injectors, fuel pumps, TPS, and other such items, but may contract out various components such as the ECU design to a third party that specializes in the manufacture of EFI components based on its design drawings and specifications.

The components in the OEM EFI system are not proprietary, and component specifications-data can be found, determined through experimentation, or determined by a third party. The ECU design is different in that the ECU programming will probably be intellectual property, and as such, how the EFI system ECU controls the EFI system will be difficult to ascertain. Getting this information from the OEM will be difficult at best.

Efficient and accurate fueling of the engine is the purpose of the EFI system. There is a lot of components feeding the EFI system ECU with the information necessary to do this. Knowing some basics about the existing EFI system, or the EFI system you are putting together will be extremely beneficial.

EFI System Considerations

Every EFI system uses components to determine the engine load characteristics. There are three primary EFI fueling profiles. There is Speed-Density (SD), Alpha-n, and MAF fueling profiles. MAF fueling will not be discussed herein.

The engine load parameter is based on the Throttle Position Sensor (TPS), or Manifold Absolute Pressure (MAP) sensor.

When a MAP sensor is used to determine engine load, the ECU fueling profile is referred to as a Speed-Density (SD) fueling profile.

Speed-Density gets this name from "Speed" meaning RPM, and "Density" referring to the air mass in the intake manifold system.

When a throttle position sensor (TPS) is used to determine engine load, the ECU fueling profile is referred as an Alpha-n fueling profile.

Alpha-n gets this name from "Alpha" referring to the throttle angle, and "n" for the engine RPM. When using an Alpha-n fueling profile, there is no direct measurement of the mass of air or the volume of air entering the engine. The Alpha-n fueling profile is not as refined as an SD fueling profile.

Each fueling profile has pros and cons. The fueling profile you choose will depend on your application; however, as emission regulations continue to become more stringent, an Alpha-n fueling profile may not be the best choice.

Depending on your requirements and the ECU being used, there can be a third choice, that of a blended fueling profile combining Speed-Density and Alpha-N fueling profiles together depending on your requirements. The Honda 1985-1986 FI model fueling profile is an SD and Alpha-n fueling profile depending on engine RPM.

For a given load-RPM pairing, there is a defined air mass being drawn into the engine. For an SD fueling profile, the ECU determines from the sensor inputs where the engine load-RPM is and uses the various table(s) to determine the fuel required to match the air mass entering the engine.

Speed-Density fueling uses the inlet air temperature (IAT) sensor signal in conjunction with the MAP sensor signal to compute the air density. The ECU then uses this value and engine RPM to determine the required engine fueling.

When the load-RPM is not exactly in the cell related to the load-RPM, the ECU uses the load-RPM settings that are closest to load-RPM requirement and extrapolates a fuel requirement for this.

The air density value is generally not used with an Alpha-n fueling profile.

The fuel required for any given load-RPM pairing is further refined from other secondary sensor inputs such as the engine coolant sensor (CLT), air inlet temperature (IAT), and AAP (barometric/atmospheric/altitude pressure) to name a few.

A cold engine on initial start requires additional fuel above that required for an engine operating at normal operating temperature to ensure enough fuel gets atomized for combustion. This is because only a certain amount of the fuel injected into the engine will vapourize to allow the engine to start and operate.

Cold engine start(s) and the additional fuel to make the engine start, is a quandary that engine and engine control system designers agonize over. Engine temperature is the designer's friend. Engine temperature ensures proper fuel atomization for reliable combustion at normal engine operating temperature.

Too little engine heat as is the case with a cold engine start and the ECU enriches the air/fuel mixture causing a fuel rich environment. The same occurs when the engine operating temperature is greater than the designed normal engine operating temperature. Extra fuel is used to cool the engine cylinder(s).

There are three 1D maps that the ECU uses to ensure that a cold engine will start and operate. These are the Cranking Enrichment, After Start (ASE) and Warm Up (WUE) Enrichment tables.

The Cranking Enrichment table is used just before the engine starts. The ECU uses this table to determine the amount of additional fuel that should be needed to start the engine. The ECU adjusts the injector pulse width such that an additional percentage of fuel is added to the required fuel and injected into the engine for an engine start.

On initial start, the ECU further refines the air/fuel ratio based on the engine coolant temperature and engine RPM. The ECU no longer refers to the cranking enrichment table for fuel enrichment, but refers to the after start (ASE) and warm up (WUE) tables.

ASE is an interim, transition fuel enrichment that is used immediately after engine start and before the WUE kicks in. ASE is used as a short-term enrichment to stabilize Lambada at engine start to prevent a lean fuel condition on engine start. If the engine starts immediately, but the WUE has not fully kicked in, the ECU can utilize the ASE table to compensate to maintain a stable idle and the required AFR. Once WUE kicks in, and the idle and AFR are stable, the ECU no longer refers to ASE table.

Engine fuel enrichment on cold engine start, cranking, ASE, or WUE enrichment, is a percentage-based addition-subtraction, and results in an increase or decrease in injector pulse width.

As the engine warms up using WUE, the amount of fuel enrichment is reduced until the engine is operating at normal operating temp and the fuel enrichment is "0". This value is represented as an enrichment percentage of 100%. A percentage above 100% increases the fuel injector pulse width, increasing the amount of fuel delivered to the engine. A percentage below 100% decreases the fuel injector pulse width, reducing the amount of fuel delivered to the engine. There is no fuel enrichment when the percentage is at "100%".

The electrical system voltage impacts on the fuel delivery to the engine. The fuel injector is designed to operate at normal electrical system voltage, approximately 14.2 VDC (alternator reference voltage). When the voltage increases above this base reference voltage, a voltage percentage correction factor is applied to the fuel injector pulse width because it takes less time for the fuel injector to open and start flowing fuel into the cylinder. Conversely, when the voltage is less than the base reference voltage, it takes longer for the fuel injector to open and start flowing fuel into the cylinder.

The health of the electrical system and the components that make up the electrical system such as the alternator and battery are key elements in ensuring that the EFI system is operating correctly at all times. This is not only true for an EFI system, but for all ignition systems.

The ECU monitors other secondary sensor inputs such as the ambient inlet air temperature (IAT) and engine coolant (CLT) sensor signals continuously to further refine the engine fueling requirements. If there is a need to adjust the air-fuel mixture, the ECU will increase-decrease the fuel injector pulse width, and add or subtract fuel to compensate for the requirement.

The ECU determines if additional fuel is required when the engine is operating at a higher engine operating temperature than normal and could add a fuel correction value that will add fuel so that the engine operates in a more fuel rich condition, minimizing or eliminating the possibility of engine damage/failure.

If the IAT is high, or the engine is operating at higher altitudes, the ECU adjusts the air-fuel mixture to suit. When you return to sea level or there about, the air density increases, and the ECU again adjusts the air-fuel mixture to suit.

The IAT signal to the ECU is also used to safe guard engine operation, by applying, if necessary, a timing retard correction in accordance with (IAW) the IAT timing retard table. This timing correction is in degrees of timing retard.

The ECU uses the IAT timing retard in conjunction with the VE and spark tables.

The aim of these fuel injector plus-minus pulse width corrections is to ensure that the correct amount of fuel is injected into the engine for a correct air-fuel mixture that will ensure successful engine operation, meet emission standards, maintain optimum fuel economy and to prevent the possibility of engine damage/failure.

Carburetor aficionados may mention that carburetors can achieve the same results, or very close. Carburetors are a "dumb" apparatus. Engine RPM and AAP are the two external parameters that affect a carburetor. As RPM increases, more air mass is required for proper combustion of the air/fuel mixture. This air mass is drawn into the carburetor, then through the carburetor venturi and out to the engine air chamber. The inlet and outlet of the carburetor throat is the same size, but the carburetor throat is reduced between the inlet and outlet of the carburetor throat causing the air mass to flow faster through this area because of the venturi effect, known as the Bernoulli Principle. When the air mass flow rate increases, the pressure in the carburetor venturi drops below AAP, and fuel is pushed out of the carburetor fuel bowl by the AAP into the air flow for combustion. The converse is the same, air mass flow reduces, the amount of fuel pushed out of the carburetor fuel bowl decreases.

Tuning a carburetor is a series of compromises, some you can control, some you cannot. Carburetor inlet throat for reliable low speed operation can be small, for a high-power application, better to have a larger carburetor throat. To have both, a compromise has to made regarding the size of the carburetor throat.

The idle, main and slow-speed jets that control fuel flow in the carburetor is a compromise. Jetting of a carburetor may be appropriate for the location of the motorcycle, sea level, mountainous regions, but not for both, or you have extrapolated and are using idle and main and high-speed jets that are a compromise but allow for relatively good engine operation regardless of location.

These concerns are not relevant to an EFI system. Once the EFI components specifications have been entered into the ECU programming, the various tables have been adjusted to suit, and the sensor correction tables have been adjusted, the ECU will determine the correct amount of fuel to be delivered to the engine based on the increase/decrease of air flow, air density changes due to the ambient air temperature, and other external factors affecting the operation of the engine.

Exhaust Systems

Need to branch out and have a quick discussion about switching exhaust systems. This is applicable to carbureted engines as well.

Engine exhaust systems are designed to ensure the correct air flow through the engine from intake until out the tailpipe. Considerable amount of work is done to manage the exhaust system pressure waves that are in the exhaust pipe resisting and pulling exhaust gases from the engine. Any change to the exhaust system back pressure and pressure waves, will impact on the gas flow through the engine.

A good read regarding this is "Stealing Speed – The biggest Spy Scandal in Motorsport History" by Mat Oxley.

Exhaust system pressure waves that increase the back pressure on the engine, reduces air mass flow through the engine, and there is an increased pressure applied to the injector spray tip and FPR.

With an increase in the MAP sensor reading, the ECU will adjust the fuel injector pulse width to increase the amount of fuel delivered to the engine because of the increase in air mass pressure in the intake manifold. This could have the engine operating in a fuel rich condition.

Conversely, when the exhaust system back pressure is reduced, intake manifold pressure is reduced allowing for increase air mass flow, the ECU will adjust the fuel injector pulse width to decrease the amount the amount of fuel delivered to the engine. This could result in the engine operating in a fuel lean condition.

Manufacturers design exhaust systems such that exhaust pressure waves aid/assist in gas flow through the engine. Exhaust system back pressure and pressure waves are part of the engine design. Changing the engine exhaust system for an aftermarket, or other OEM exhaust system(s) will probably change the exhaust system back pressure

and pressure waves affecting the engine performance. Most of us would not notice a difference in engine performance, but those who are riding more powerful and high-performance motorcycles may.

How does this affect a fuel delivery system not specifically impacted by the exhaust system? As mentioned, changing the exhaust system for an exhaust system not specifically designed for the engine can affect the air flow through the engine, and if so, may require the ECU settings to be adjusted to accommodate the change in exhaust system for optimal engine operation. Carburetors require the same, but the adjustments required will be determined through experimentation.

Fuel injectors are another component that require a good discussion, but this will be done later in this document.

An EFI system is affected by small modifications and requires either a change in the fuel tuning, or as a minimum, a look at the settings in the VE and spark tables.

A quick intro and discussion into types of EFI modifications. It must be realized that most common upgrades, or modifications, never alter the ECU air-fuel mapping.

Chip Upgrades/Modifications - This is the ability to replace or modify the various chips in the ECU. The CFI system ECU for the 1985-1986 Gold Wing CFI models cannot be modified this way, and if you wanted to and could do the work yourself, you would need the proper equipment. If you were not able to do this work yourself, finding someone with the skillset required would be extremely challenging.

The CFI system ECU design specifications are not available, and because of this, the CFI system ECU programming would have to be reverse engineered, no mean feat. Finding a shop that specializes in this work will also be difficult.

Piggyback Controllers - these are a class of add-on boxes that generally "fool" the ECU into providing a different amount of fuel than what the ECU would have determined from the sensor inputs of the OEM designed EFI system. This type of controller may also alter ignition timing. Piggyback controllers "fool" the ECU without modifying the ECU engine tune. These boxes can be an effective means of changing the fuelling and/or ignition timing for a stock or slightly modified motorcycle.

The piggyback controller may read a number of sensor signals depending what the piggyback controller is expected to do. These signals are either modified by the piggyback controller, or used by the piggyback controller to achieve the aim of the piggyback controller, changing the fueling requirement or ignition timing.

Most piggyback controllers that alter the engine fueling use the Alpha-n fueling map as the base fuelling map to alter the fueling to the engine. This can be a conflict depending on the motorcycle in question because many motorcycles use an SD fueling profile for some or all of the fueling requirements.

In other cases, the piggyback controller alters the coolant temperature signal to the ECU that allows the ECU to use its 1D CLT map to richen or lean out the fuel delivered for engine operation.

The ECU engine tune is generally never changed, just bypassed.

This type of controller is used by many to improve the overall performance of their motorcycle without having to learn about the intricacies of EFI systems, or finding a shop that could do an EFI engine tune upgrade.

These controllers are model-specific and cannot, should not, be used on a different motorcycle.

Be careful when, or if you use a piggyback controller because you can affect the lean/rich fuel condition of your engine.

You may want to separate what the main ECU does and what a second ECU would do. This is mentioned below – "Using an Aftermarket ECU as a Second ECU". As will be mentioned, one ECU controls engine fuelling

requirements, one ECU controls engine ignition/timing. If you have a carb model motorcycle, you will want a piggyback controller specifically for ignition timing.

Engine Management Software - may be purchased for your ECU if available. You will be able to adjust the ECU settings to make changes to the engine tune, directly affecting the engine operation. Having this software will require you to be your own DIY EFI technician, to delve into the capabilities of the software package to get the most out of your purchase.

ECU Replacements – complete replacement of the EFI system ECU. These ECU replacements may have more capabilities than the original EFI system ECU, and come with supporting software. You must be prepared to delve into the EFI requirements and be willing to expand your knowledge so you can effectively use the new software and ECU in the EFI system.

Using an Aftermarket ECU as a Second ECU - this is where you have a separate ECU to control either fuel or ignition timing, but not both. This is different from the ready-made piggyback units in that you are doing the tuning of the new unit to meet your requirements. You will have more control over the end result than if you use a piggyback unit. The components of the EFI system do not care where the component signals go to, or where the component signal for operation comes from. This allows you to adjust the fuel, or ignition and engine timing to optimize the engine operation.

DIY Upgrades, Changes of Components - Understanding how an EFI system works and the impact of component changes is paramount when making these changes. You can affect the engine operation such that it may operate worse than before the changes.

EFI Conversion Projects – for the DIY Aficionado - Allows you to use components that have been proven to be successful with this type of project. Information regarding the specification(s) for these components are generally available and you should be able to find information on the settings required for your chosen ECU. There is a requirement to be skilled/handy with being able to fabricate necessary parts to support your project. Most who venture down the road of an EFI conversion project, never bring the project to fruition, it's a lot of work and not the most inexpensive project that you can try.

There are benefits to this type of project. Parts for older motorcycle carburetors are not that plentiful. The expertise and knowledge available for carburetor rebuilds is quickly diminishing.   The motorcycle world is going EFI. Parts for an EFI conversion are plentiful. Most automotive EFI components can be made to work, and there is a lot of availability.

An EFI conversion has one main benefit. Once the EFI system is installed and engine tuning is complete, you should have many miles and years of trouble-free riding.

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The Beginning

Honda first introduced the Computerized Fuel Injection (CFI) system on the 1982 CX500 Turbo motorcycle, followed closely by the 1983 CX650 Turbo motorcycle. There were a few changes in the CFI system between these two motorcycles, but nothing substantial. The third generation of the CFI system was the 1985-1986 Gold Wing fuel injected (FI) model motorcycles. There were changes made to suit the 1985-1986 Gold Wing FI models because these motorcycles did not have a turbo boosted engine, redundancy was built into the system to ensure trouble free motoring, and the CFI system was designed for waste spark ignition.

The CFI system uses Speed-Density (SD) and Alpha-N fueling profiles depending on the RPM range.

Using SD and Alpha-n fuel profiles together on the CFI system of the '80s was ahead of its time. This is a strategy used by the Japanese motorcycle OEMs so that the appropriate fueling profile is used in the area of engine operation that most benefits from an SD or Alpha-n fueling profile. The SD fueling profile is used in the cruise, lower RPM ranges and idle, and Alpha-n in the higher engine powers.

The operation of the CFI system is one of longevity, and trouble-free riding. The components that Honda used in the CFI system are very robust and do not fail as often as a lot of people would think. When components do fail, with the exception of a few key components, alternative components have been sourced and used as replacement(s).

The components of the CFI system have been discussed, but more discussion is needed, as does the operation of the CFI system.

The CFI system operates the same as a modern day EFI system and uses the same, or similar sensors as the modern day EFI systems do.

The CFI system ECU was the first ECU in the motorcycle industry to be a "map" based ECU starting with the 1982 CX500 Turbo motorcycle. The size of these "maps" is unknown, but suffice it to say, the "maps" are significantly large and detailed enough to provide the information needed for very good engine operation.

The CFI system ECU has an internal diagnostic program, a barometric (AAP) sensor that is used to sense changes in barometric pressure (altitude versus sea level and anywhere in between) so that the fuel tune can be adjusted to suit. The CFI system ECU cannot be reprogrammed without a lot of time, effort and resources being expended, and the programming code is not available.

There are two CFI system adjustments that can be done to ensure correct engine operation. There is a cylinder bank synchronization, and a throttle position sensor (TPS) adjustment.

The cylinder bank synchronization is between the left (cylinders 2 and 4) and right (cylinders 1 and 3) cylinder banks. You cannot synchronize the cylinders specific to one side.

The TPS adjustment is only done if the TPS calibration is outside calibration limits, or if a new TPS is installed.

The CFI system ECU internal diagnostic program can be considered a forerunner to the on-board diagnostic (OBD) system(s) used in more modern vehicles. The main difference between the CFI system ECU diagnostic program and the modern day OBD systems is that modern day OBD systems store the error codes for future reference. The CFI system ECU diagnostic program does not. Once you turn the ignition key to the OFF position, the error code is not stored and disappears. You will have to wait until the next time you turn the ignition key to the ON position for an error code to be generated; however, when this happens, there is no guarantee that the previous error code generated by the CFI system ECU will reappear. You may have to be patient until the next occurrence of the error code.

The CFI system is the first system that most people go to when there is an issue with the engine operation. This is a mindset that is prevalent with the 1985-1986 FI models. I mention this because I have been caught up in this as well. Thinking that the CFI system is the issue when an engine problem occurs can easily be dispelled by simply looking at the dash at the FUEL SYSTEM indicator light, if it is not on, look elsewhere for the issue.

Honda's CFI system has a couple of specialized aspects. Camshaft sensor(s) indicate to the ECU the engine phase, specifically where the intake and exhaust valves are. It uses two camshaft (GR/GL) sensors that are used to provide a waste spark system, ensure quick starting, and emulates a sequential fuel injector system.

It has two pressure balance (PB - MAP) sensors. When one fails or is faulty, the engine will still operate as per normal using the second PB sensor. When both PB sensors fail or are faulty, the ECU reverts to a limp home mode.

The camshaft sensors are similar to the PB sensors in that if one fails or is faulty, the engine will operate as per normal on the second camshaft sensor. If both camshaft sensors fail or are faulty, the engine will shut down and not start.

The fuel system is pressurized by a high pressure/high flow fuel pump to an operating pressure of 28 to 34 PSI, and maintained at this pressure by a vacuum operated fuel pressure regulating (FPR) valve.

The fuel injectors used in the CFI system are low impedance injectors, with a resistance of approximately 3 OHMs. This can be problematic with an ECU. The CFI system ECU injector circuits are low amperage circuits, as are those used in today's modern EFI systems, and use a circuit current of less than approximately 2.5 amps. Using OHM's law, low impedance injectors would have an injector circuit current of 4 amps or more that may cause the injector circuit(s) to fail, and the CFI system ECU as well.

To protect the CFI system ECU injector circuits, a resistor pack is installed in the injector circuit that further restricts current flow in the injector circuit for these low impedance fuel injectors to be used successfully with the CFI system ECU.

High impedance injectors with a resistance of approximately 9 to 14 OHMs do not affect an ECU's injector circuits and can be used without the use of additional resistors in the injector circuit. Replacing the CFI system low impedance fuel injectors with high-impedance fuel injectors may be possible, but I have not found any information that this has been done.

Turning the ignition key to the ON position causes the electronic dash to go through a start-up sequence and indicate to you the state of the motorcycle before engine start.

The dash has several features that enhance your riding enjoyment and ability to monitor the operation of motorcycle systems.

As with all motorcycles, there are dash trouble lights. Two of these trouble lights need explanation. The FUEL and FUEL SYSTEM indicator lights.

The FUEL indication light alerts you to a low fuel tank level and is self-explanatory.

The FUEL SYSTEM indication light has nothing to do with the fuel system. This indication light is the OEM check CFI system component indication light. It alerts you that the CFI system ECU has generated an error code that relates to one or more of the CFI system components. You need to determine what the error code relates to and need to correct the issue.

The CFI system ECU goes through a start-up sequence and determines that the CFI system component signals are within specification, or not. If any of the monitored sensor(s) are out of specification, or have failed, an error code is generated by the CFI system ECU, and the FUEL SYSTEM dash indication light is illuminated to alert you that there is an issue with the CFI system.

The CFI system ECU cannot be modified, reprogrammed, and/or changed by the operator. Modifications to the CFI system ECU without a significant investment in time, effort and resources, and the programming code is not available.

1985/1986 Honda Gold Wing GL1200 Computerized Fuel Injected Models – 19 June 2023

Should the CFI system ECU internal components start to degrade because of time and these do, but are not sufficient enough to have the CFI system ECU generate an error code, engine performance can be affected. It is at this time that you need to consider other options regarding the CFI system ECU.

There can be issues with the CFI system that do not have the CFI system ECU generate an error code, but does affect the engine operation. A candidate for this is the throttle position sensor (TPS).

The TPS is a basic rheostat that operates with a 0 to 5 VDC power input and outputs a voltage signal to the CFI system ECU that the CFI system ECU uses to assist in determining the engine fuel requirement.

An aftermarket TPS showing the internal workings:

This picture of an aftermarket TPS shows the activating arm that needs to be modified to engage the throttle plate arm:


We generally ride our fuel injected (FI) Gold Wing(s) in a narrow RPM range, slow speed and cruising. Over time this causes wear to a specific "spot" on the internal workings of the TPS. When this happens, engine operation is affected because the signal being sent to the ECU for a specific operating RPM is not constant, or is out of specification for that specific engine RPM. This causes the engine to possibly misfire, or have an annoying stumble at a specific engine RPM.

This web site, https://autoditex.com/page/throttle-position-sensor-tps-22-1.html, has more information regarding the TPS. These TPS graphs are courtesy of this web site.

This first graph is a TPS In good working order. The oscilloscope profile indicates a smooth voltage rise and a quick collapse:
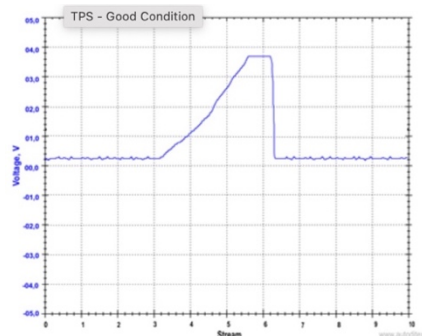
This second graph is a faulty TPS. The smooth voltage rise seen in the first graph is riddled with voltage spikes that indicate that the internal discs are defective:
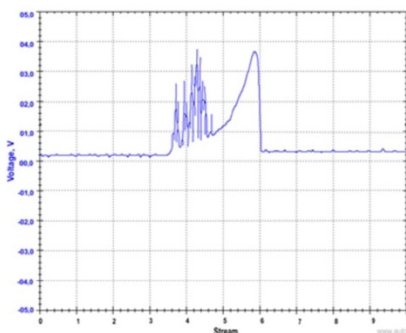
Troubleshooting this is not that easy because the symptoms could be related to ignition, or fuel delivery, and still no error code has been generated. The TPS may work quite well for an idle condition, or when riding in the higher RPM range further aggravating your ability to determine what the issue is.

With everything being in good working order, and much like the modern car of today, you press the start button and the engine will start, no need to use a choke as there is not one. The CFI system ECU has determined the correct fuel requirement for the engine to operate at normal operating temperature and idle RPM, takes into account the various secondary sensor inputs, adjusts the fueling requirement to suit.

After all is done, the engine should settle into a stable idle, and you are ready to enjoy many enjoyable miles riding your FI Gold Wing.

EFI System Components

These are components that are used in all EFI systems, and most are used in the Honda CFI system. It will be noted whether the EFI component is used in the CFI system

Electronic Control Unit – this is the "brains" of the operation. It contains the microprocessor that contains the EFI system programming. Used in the CFI system.

Main Relay – This relay controls the power to the EFI system. Used in the CFI system.

Throttle Position Sensor (TPS) – This sensor is a basic potentiometer. Has a 5 VDC input, ground and signal wire. This sensor provides a 0 to 5 VDC signal to the ECU with a voltage greater than "0" indicating more throttle has been applied. This sensor is used to indicate the throttle position relative to the engine RPM. It must be mentioned that a TPS can be affected by heat. Used in the CFI system.

Engine RPM – this signal is generally generated from a coil signal or an injector pulse. Used in the CFI system ECU programming.

Manifold Absolute Pressure (MAP) – A secondary sensor input for the EFI system for engine start, idle and low RPM engine operation. This sensor has a linear voltage output in relation to the engine manifold pressure. A high vacuum indicates a small throttle opening, or low RPM loads. A low vacuum indicates large throttle opening(s) and high RPM loads. Used in the CFI system.

The CFI system calls these sensors Pressure Balance (PB) sensors, and measure the intake manifold pressure downstream of the fuel injectors.

Intake Air Temperature (IAT) Sensor – A secondary input sensor used by an EFI system to fine tune the engine fueling requirements. This sensor is located on the air box lid. Used in the CFI system.

Coolant/Engine temperature (CLT) – A secondary input sensor used by an EFI system to fine tune the engine fueling requirements. Used in the CFI system.

The ECU monitors this sensor during all engine operations.

Oxygen Sensor (O2) – Wide Band (WBO2) or Narrow Band (NBO2) – A secondary input sensor used by an EFI system to fine tune the fueling requirements at start, during normal operating conditions, and to meet emission standards. Not used in the CFI system.

Crank Position Sensor (Ns) – This sensor provides the ECU with the exact position of the engine cylinder pistons as the engine rotates through the engine (Otto) cycle of 720 degrees. This sensor is generally located near or on the crankshaft. Used in the CFI system.

The Ns sensor is a variable reluctance (VR) sensor that measures changes in magnetic reluctance to provide the ECU with the angular position of the crankshaft so the ECU can calculate engine speed (angular velocity).

Crank Trigger Wheel – The crank trigger wheel is generally found on the crankshaft. The trigger wheel tooth count must be evenly divided into 320. The trigger wheel may also have a tooth removed to indicate engine phasing. Used in the CFI system.

Cam Shaft Sensor (Gr/Gl) – This sensor provides information to the ECU regarding the position of the inlet and exhaust valves, called engine phasing, and is also an input signal to the ECU as a second rotational input for sequential fuel injection, and/or coil-on-plug (COP) operation. This is in conjunction with the crank trigger wheel signal. The camshaft sensor can be used instead of the crank trigger wheel, but the size of this camshaft trigger wheel may be challenging to use. Used in the CFI system.

If you only use a crankshaft position sensor, the ECU can only be sure of the engine crankshaft angle over a crank rotation of 360°. This limits the engine fueling and ignition options to semi-sequential fueling, and operate ignition in a wasted-spark configuration.

There are 2 revolutions of the engine crankshaft to complete a full engine cycle of 720°. Using a camshaft sensor allows the ECU to correctly determine a complete engine phase for an engine cycle of 720°. This is advantageous, resulting in better ECU operation even if it is not intended to use full sequential fueling, or coil-on-plugs (COP) or coil-near plugs (CNP).

Variable Reluctance (VR) and Hall Effect Sensors

VR sensors are used for the crank and camshaft sensors. These work well, can be used in high temperature areas, and last a long time.

The crankshaft VR sensor can be used with any new ECU chosen. The signal resolution is good. May have to increase the air gap between the trigger wheel and sensor if a new non-OEM trigger wheel is used.

The camshaft sensors are VR and work well with the OEM CFI system design. The newer aftermarket ECUs do not use two camshaft sensors. There are issues with a single VR camshaft sensor in that the signal resolution because of

the speed of the camshaft (half that of the crankshaft speed) can cause engine sync losses. It is recommended that a Hall Effect sensor be used in its place.

Hall effect sensor(s) are very good for low-speed applications. These do work in high temperature areas, but check the specifications for heat rating.

Hall effect sensor(s) require a 5 VDC input for operation. Some ECUs require the hall effect sensor(s) to have a "pull-up" or "pull-down" resistor connected. A "pull-up" resistor is connected between the 5V power supply to the sensor and signal wire of the hall effect sensor. A "pull-down" resistor is connected between the ground and signal wire.

Fuel Injector(s) – Fuel injectors can be low high impedance depending on the EFI system design. If using high impedance fuel injectors, no additional injector circuit resistors will be required. If using low impedance injectors, there will be a requirement for additional injector circuit resistors will be required. Low impedance fuel injectors are used in the CFI system.

Coils – The purpose of an ignition coil is to convert the low current from the battery into enough power to ignite the fuel, start the engine, and have the engine operate throughout its operating range. Used in the CFI system.

Coils are step-up transformers turning a 12 VDC supply into 20,000 or more volts depending on the coil turns ratio between the primary and secondary iron cores in the coil.

Spark Igniters – these units, generally called coil drivers or ignition modules, are used to turn a coil(s) grounding circuit on/off so that a "charge" can be built-up in the coil. When the ECU grounding circuit is removed from the coil driver, the coil discharges the coil charge to ground through the spark plugs, firing the engine cylinder. Used in the CFI system.

Fuel Pump Relay – The fuel pump relay is controlled by the ECU, and controls the on-off operation of the fuel pump. The ECU provides a ground circuit for the relay to operate. Used in the CFI system.

Fuel System Fuel Pump – The fuel pump is a high pressure/flow fuel pump rated in LPH, and should be capable of providing upwards of 65 PSI. There is an internal, integral pressure relief valve that will recirculate fuel inside the fuel pump if the fuel pump outlet is blocked for some reason. The fuel pump should have an internal non-return valve to maintain fuel pressure in the fuel system. Used in the CFI system.

Fuel Filter – there is a fuel filter downstream of the fuel pump installed before the fuel rail. Used in the CFI system.

Fuel Pressure Regulator (FPR) – The fuel system is a return fuel system. The FPR regulates the fuel system pressure to maintain a fuel pressure differential across the fuel injectors as designed, taking into account the vacuum/boost pressure on the fuel injector spray tip. Used in the CFI system.

CFI system FPR. The FPR on the right is the OEM FPR, the one on the left is an aftermarket FPR:

Idle Air Control (IAC) – all EFI systems require additional combustion air when starting, for idle and during periods of deceleration. This is achieved with an electric stepper type "air" motor controlled by the ECU, or a passive IAC system. A passive, IAC system used in the CFI system.

IAC Valve:

Bank Angle Sensor (BAS) – bank angle sensors are used to turn off the fuel pump should the motorcycle exceed a predetermined angle such as laying on its side. This turns the fuel pump off as a safety issue. This was a first for the motorcycle world. Used in the CFI system.

Closed Loop Operation – Closed Loop operation is when the ECU is controlling the air/fuel mixture with an input from the O2 sensor. The closed loop operating mode is generally used during times of cruising and low engine loads. Not used in the CFI system.

Open Loop Operation - Open loop operation is generally reserved for operating at high engine loads and the ECU does not consider the O2 sensor input for the fuel calculations. It is also used on initial engine start, then reverts to closed loop operation just after engine start. Not used in the CFI system.

Atmospheric Sensor (Barometer – AAP) – A secondary input sensor that measures atmospheric pressure in "real" time for efficient engine operation. The barometric sensor is used to determine the engine fueling requirements at the various operating altitudes. Used in the CFI system.

Electronic Fuel Injection Improvements

There have been improvements to the EFI system world since the CFI system was installed on the 1985-1986 Honda Gold Wings. The CFI system of the 1980s was the precursor to Honda's PGM-FI system. Much of the CFI system is still used in the Honda PGM-FI system.

There are many new components used in modern day EFI systems. These components have been incorporated in the EFI systems to enhance emission standards, improve fuel economy, and other aspects.

A couple of these components are:

Knock Sensor – this sensor senses preignition (detonation) and when a "knock" is sensed the ECU enriches the air/fuel mixture, or retards the ignition timing to compensate.

Vehicle Speed Sensor (VSS) – Another secondary input that the ECU can use to adjust the air/fuel mixture if fitted.

Oil/Fuel Pressure Sensors – a secondary sensor input if fitted. May allow for engine protection control.

Exhaust Gas Oxygen Sensor (EGO) – a secondary sensor input that monitors the air-fuel ratio of the exhaust and provides sensor input to the ECU to fine tune the air-fuel mixture primarily at idle and low RPMs

Honda OEM CFI System Components

The CFI system is now some 41 years old, and is still being widely used. Most owners will not upgrade the CFI system unless a component fails, and when this happens, a lot of dialogue is exchanged to have the issue corrected.

Alternate components are available, but a lot of research is sometimes required to find a suitable replacement component. I mentioned earlier on that care must be taken when replacing CFI system components such that engine performance is not adversely affected. This means that when a change is made, the impact of this change must be understood and accepted.

Let's start with the more common changes to the CFI system.

Used Replacement Components/Parts – These are available on the used market and are from these motorcycles when they are scrapped or parted out. Some of these components, when available, command a premium dollar. The issue with these is that these components are some 38 years old, used and the longevity of these components is an unknown.

Crank Sensor (Ns) – these sensors are Variable Resistance (VR) sensors, are reliable and do last a long time. You can install the Ns sensor in either the upper or lower mounting position and engine operation will not be affected.

When this sensor fails, you can use a crank VR sensor from a GL1500 – have to modify the sensor mounting position to make this sensor fit properly, replace it with a used CFI system Ns sensor, install a PG sensor from a carbureted GL1200 1985 to 1987 model, or do the research to find a suitable, modern VR sensor alternative that will fit in the appropriate location.

My preference for an Ns sensor replacement is a PG set from a 1985 to 1987 Honda GL1200 Aspencade. These sensors will fit in the exact same spot with no modification to the sensor mounting position.

This PG set allows you to install both PG sensors and use only one. The second sensor is a spares sensor so that if the sensor being used fails, you can easily change the Ns sensor connection under the shelter without having to get into the timing belt area to change out the Ns sensor. You will have to change the 4-pin connector to a 2-pin connector to connect the new sensor to the wiring harness.

The GL1500 Ns sensor can be used and installed in either the upper or lower mounting position. You will have to modify the mounting screw bosses to adjust the NS sensor so it is in the proper installed position.

A used Ns sensor, if one can be found, is still a used Ns sensor. New Old Stock (NOS) Ns sensors are extremely rare and are generally no longer available.

Throttle Position Sensor (TPS) – The original CFI system TPS is no longer available. The alternative TPS is used the most is one from an early model Honda Civic-Prelude. This TPS must be modified to have the TPS activating arm lengthened to connect to the throttle plate shaft for numbers 2/4 cylinders.

The Speeduino ECU calibrates the TPS such that it knows when the throttle valve is closed, idle state, and when the throttle valve is fully open – wide open throttle (WOT).

There is an issue with these aftermarket TPS units as mentioned previously. New TPS units do not guarantee that the unit will not be faulty. These units are inexpensive to make, and have limited quality assurance-control even though these units are a key element in an EFI system. Faulty, new TPS units have been reported on several occasions. When changing out and adapting an aftermarket TPS, it is recommended to have several on hand just in case one does not work.

Fuel Injectors – the CFI system fuel injectors are low impedance injectors that have a flow rate of approximately 280 cc/min. These are a solenoid activated, constant stroke pintle type. There are two types of fuel injectors, one with a pintle style spray tip, the other a disc spray tip. Recommend you use a similar fuel injector with a pintle spray tip.

OEM and aftermarket fuel injectors. The OEM fuel injector is on the right. The aftermarket fuel injector will fit and can be used but it has a tested flow rate of approximately 240 cc/min compared to the OEM fuel injector flow rate of 280 cc/min:

These OEM injectors, Denso 195500-1070, are no longer available. The good news is that these fuel injectors are very robust, and can be cleaned, flow and leak tested. You should take note of the length of the fuel injector spray tip. The OEM spray tip is longer than an aftermarket fuel injector.

Early model Honda Civic-Prelude low impedance injectors can be used, but these generally have a lesser flow rate then the original CFI system fuel injectors.

Using fuel injectors that flow more or less fuel flow can impact on the engine performance. A fuel injector with more fuel flow could have the engine operating in a fuel rich condition that while beneficial at higher engine powers, not so much at lower powers and at idle. Conversely, a fuel injector that has a lesser fuel flow, can have the engine operating in a lean fuel condition at the higher power range.

The above scenario is based on the fact that the CFI system ECU programming does not change when components are replaced. The CFI system ECU will determine the requisite fuel load and open-close the fuel injector to suit as if the original CFI system fuel injector(s) were installed.

Manifold Absolute Pressure (MAP) – These sensors are called Pressure Balance sensors (PBR/PBL) and there is one connected to each cylinder bank. The CFI system works extremely well with two functioning PB sensors, but has been designed to work effective with just one PB sensor functioning. If both PB sensors fail, the ECU goes into a limp home mode where ignition timing and fuelling is locked. These sensors are located under the shelter just above the coils.

An alternative to these PB sensors is a MAP sensor from a late model Suzuki motorcycle. These Suzuki sensors are a more modern technology, and have virtually the same linear voltage signal output.

Spark Units (Coil Drivers) - these have proven to have a long life. There have been no alternative coil drivers identified as replacements for these units.

Coils – these 3 OHM coils, are robust, and last a long time. GL1500 coils are a good alternative, but require the mounting bracket to be modified. Several aftermarket coils are available as well.

Camshaft Sensors (GR/GL) – these VR sensors last a long time, but no alternatives have been identified. These sensors are used on the 1982 CX500 and 1983 CX650 Turbo motorcycles. Several owners have used an LX579 sensor as a replacement. Have not heard of anyone in the Gold Wing world doing the same.

Engine Control Unit (ECU) – there is no alternative for a faulty CFI system ECU except for a used, or if you can find one, a NOS CFI system ECU, or a complete replacement with an aftermarket ECU. When these CFI system ECUs are available, the price is commensurate with the scarcity of the unit.

The alternative is to replace the CFI system ECU with an aftermarket ECU. This is a significant investment in time, resources and cost, but can be beneficial.

The 1985-1986 CFI system ECU has no ready-made ECUs available on the aftermarket. There are ECU suppliers that can assist, and may be an option depending on your budget.

Research indicates that a DIY ECU replacement project will probably be the way ahead. A project such as this is not inexpensive, and requires a significant time investment, but may be your only viable option to keep the ride of your choice on the road.

Fuel System – this is an ancillary system that is not monitored by the CFI system ECU, but is critical for the correct operation of the CFI system. Comprised of a high flow-pressure fuel pump, fuel filter, and fuel pressure regulating (FPR) valve.

Idle Air Circuit (IAC) – this is a passive system designed to provide initial start air, idle air – throttle closed, and deceleration air for the engine cylinders. It is a passive system where a reed valve that is operated by cylinder vacuum, draws air into the IAC system through a thermostatic IAC valve, and discharges it to the respective engine cylinder.

An active IAC system can be installed in lieu of, and use an electrically activated stepper motor controlled by the ECU.

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Project

1985/1986 Honda Gold Wing GL1200 Computerized Fuel Injected Models – 19 June 2023

EFI Conversion Projects

There have been many Honda Gold Wing EFI conversion projects over the years. Many of these have not come to fruition, fewer have.

Some of these projects included turbochargers.

EFI components, depending on what your requirements are, are readily available. There is a considerable amount of fabrication and installation issues that must be resolved. The amount of time to do an EFI conversion can be considerable.

The expense of such a project must be realized. Keeping costs in check throughout the project is paramount to success.

You will need to learn as much as possible about the EFI system, the components, the interaction between all the sensor inputs, initial tuning, what the settings-parameters mean, and much more. This information is available, but you will have to rummage through a lot of information and boil it down to its essence.

ECU Replacement

This is by far the most demanding part of a CFI system upgrade. To replace/upgrade the CFI system ECU with an aftermarket ECU will probably require the same time, resources and possible expense as when doing an EFI conversion project.

The difference between this and an EFI conversion project is that the CFI system is already installed. All CFI system components can be used for this project. There are unknowns such as what settings should be used for the various components. CFI system component data is not available and will have to be determined through experimentation.

The age of the CFI system components can be an issue as this project is progressed and brought to fruition. It is a good time to reflect on the project and possibly consider that it's time to modernize the CFI system with newer components that are more readily available. This and other questions will come to mind as you progress a project such as this.

The OEM wiring harness can be used to connect to the new ECU. This can be achieved by replacing the OEM wiring harness connector to a connector that is compatible with the new ECU. You can also source an unserviceable CFI system ECU enclosure and use this as the new ECU enclosure, as well as using the enclosure wiring harness connector. This is a time saver and makes for an easier install.

You must do a pin-to-pin correlation between the CFI system ECU pin allocation and your new ECU. Some of the new pin allocations may not be as logical as you may think. If you are using VR sensors for crank and camshaft sensors, you need to have a signal conditioner accessory board installed to convert the VR sensor AC sine wave to a digital square wave, and understand and correctly connect the various sensor inputs.

The VR conditioner boards comes in different configurations. One conditioning board may be an inverting type, or not. This affects how the new ECU uses the input signals.

Hall Effect sensors do not need to use a conditioning board as the output from a Hall Effect sensor is already a digital signal. You will have to ascertain if a "pull-up" or "pull-down" resistor is required.

You will not have to contend with an active IAC system because there is a passive IAC system already installed. Most aftermarket ECUs can be configured to use the CFI system IAC circuit.

You must determine if the crank and camshaft trigger wheels will be used. The combination of an 8-tooth crank trigger wheel can be used in conjunction with the camshaft trigger wheel. You must decide which of the camshaft

sensor(s) you will use as the newer crop of modern ECUs only use one camshaft sensors as the additional rotational sensor.

Honda uses these two camshaft sensors primarily to have the CFI system work as a wasted spark ignition system. The other benefit is to emulate a sequential ignition-fuel injection system for quicker starts and smooth engine operation.

The CFI system camshaft VR sensors do not provide a reliable sensor signal to a modern ECU at a low camshaft speed. It is suggested that if a camshaft sensor is to be used, the camshaft sensor be replaced with a single Hall Effect sensor. This can be done; however, the space available to install a Hall Effect sensor in the GR/GL case is very limited.

If two rotational sensory inputs are not required, the best compromise for an ECU replacement project such as this, is to remove and replace the 8-tooth crank trigger wheel with a missing tooth trigger wheel, and not use the camshaft sensors. The 36-1 missing tooth crank trigger wheel is the preferred option.

You only need two rotary inputs to the ECU if you are going to do sequential fuel injection, or a coil-on-plug (COP) install.

It is to be noted that even if you are not going to do sequential fuel injection, or a COP install, the second rotary input signal is beneficial. Instead of the ECU only receiving an engine phase signal every 360° of crank rotation, the ECU will now receive an engine phase signal for every 720° of crank rotation, increasing the accuracy of the ignition timing. This is similar to the crank trigger wheel and the number of teeth on the trigger wheel. The more trigger wheel teeth (to a point) that the trigger wheel has, the better the signal resolution to the ECU for better ECU calculations.

The CFI system fuel injectors can be used. As has been mentioned these are low impedance 280 cc/min fuel injectors, and require the use of in-line resistors to reduce the current flow in the injector circuit(s). The CFI system ECU has the same low current injector circuit requirement. To accommodate this, there is a resistor pack that has a 3 OHM resistor wired into each injector circuit to reduce the current flow.

Correct fuel injector data is a critical part of a successful engine tune. This data is fuel injector specific; no two fuel injectors have the same data. How this data is incorporated into the engine tune will be dependent on the ECU being used and its tuning software.

All aftermarket ECUs will require fuel injector data to correctly use the CFI system fuel injectors. It is recommended to have the fuel injectors of choice cleaned, flow and leak tested, and if the injectors chosen do not have this data available, have the shop that is servicing the fuel injectors determine and provide the fuel injector data before use. If you do not have the CFI system fuel injector data, you will have to experiment to determine the CFI system fuel injector data.

The CFI system spark units (coil drivers – ignition modules) can be used. You will have to determine what the tuning software settings are for these units. You may want to consider upgrading these spark units to a more modern coil driver. Newer coil drivers are capable of having a single coil driver unit that can control up to 4 ignition coils. Chose a coil driver that has been proven to work with the ECU of choice. ECU settings are probably available for this coil driver.

The TPS can be used. Just about any 3 wire TPS can be used with a new aftermarket ECU.

The coils can be used. You may want to upgrade the coils with a modern coil pack but it is not necessary. These coils work well with any one of the many new coil drivers available to you for use.

Consider changing the spark plug wires and caps for what I think is better installation.

Change the steel core spark plug wires for copper core – suppression style spark plug wires. Steel core spark plug wires have a high RF interference issue. Automotive EFI systems have used suppression spark plug wires for a

considerable number of years, and considering that the 1200 engine was produced with an automotive design influence, this should not be an issue.

You need to keep the resistor spark plugs, but not the resistor in the spark plug resistor caps. You can replace the resistor with a solid copper wire, #10 in size. Replace the steel core spark plug wires with copper core spark plug wires.

Early and late model EFI cars and trucks do not use a spark plug resistor cap, but do use suppression type wires and resistor spark plugs. You could keep the resistor plug caps and revert to a non-resistor spark plug.

Moving Forward

This section will continue the discussion regarding EFI components and design considerations.

This discussion will be relevant to those who own and want to better understand, and possibly upgrade their early model Honda Gold Wing FI model, and those who want to embark on an EFI conversion project.

The many components in an EFI system all have a role to play in the successful operation of the engine EFI system, some more than others. Most of the information being presented in this discussion has been mentioned previously, but I find it good to build on an item and not have it all at once. This allows me to digest what I have read and/or viewed, and put the information into perspective.

A discussion regarding EFI engine fueling is a good place to start.

Speed-Density, Alpha-n, and MAF Fueling

The topic of which fueling profile to use is a personal decision based on what your requirements are. The bottom line is that the fueling profile you use will depend on the vehicle use, your requirements and preference. There is no right answer because engine fueling requirements, and systems used are evolving.

The three main fueling profiles are Speed-Density (SD), Alpha-n, and MAF fueling.

I will be using an SD fueling profile for the engine tune. The required components are already installed, and my research indicates that this will be the best fueling profile for my needs. This fueling profile is easily adjusted to suit an existing requirement, or a future requirement change.

There is a third option and that is a manifold air flow (MAF) fueling profile. The MAF sensor is located in the air stream just after the air filter. This engine fueling will be briefly discussed, but will not be dwelled upon.

Fueling an engine is based on the Ideal Gas Law that is quite complex. Suffice it to say that the abridged version of this law for the SD fueling profile using the MAP and IAT signals for the purpose of engine fueling requirements does not violate this law, but makes ECU computations that much easier.

Speed-Density

The Speed-Density (SD) fueling profile has been discussed in this document. The speed component is self-explanatory – engine RPM. Density is determined using the IAT and MAP sensor signals to calculate air density. The ECU then refers to the VE table, correlates engine RPM and density calculation to the VE table, and determines the amount of fuel required for engine operation to maintain the AFR required.

The density calculation is a percentage of the cylinder volume(s) at 100%.

The displacement of the engine is constant, the VE is a variable. VE is the variable used to tune the engine. VE is a measure of how well the cylinder is being filled compared to the potential volume. You adjust the VE value to achieve the desired AFR for the engine load and speed being tuned for. Once you have found this VE value that achieves the desired AFR for the engine at that particular load and speed, you have found the accurate VE value for the engine at that specific load and speed.

The VE of the engine for that load and speed will not change unless you change mechanical parts. This truism states that the engine will flow the same volume of air regardless of the engine location, sea-level or in the mountains. What does happen is the ECU determines the engine operating parameters, and calculates the required fuel for the given set of conditions. Once the VE table is properly calibrated, you will have an accurate air flow table for the engine.

Calculating air density has apparently been removed from the Speeduino programming and replaced with a base calculation for air density done by the Tuner Studio software when it does the Required Fuel (req fuel – RF) calculation. In the firmware this is corrected up-down based on the IAT Density Correction Table.

Alpha-n Fueling

An Alpha-n fueling profile uses engine speed (n) and throttle opening angle (alpha) to calculate the engine fueling requirements. Engine load is based on the alpha parameter, and doesn't measure airflow directly. The ECU uses these load-RPM values to look-up the appropriate cell in the respective ECU table. Since Alpha-n does not measure airflow directly, the ECU table used for the Alpha-n fueling profile is generally a manual table that has the individual cell values input by the tuner.

An Alpha-n fueling profile works well on engines that operate in the higher power ranges and at wide-open throttle. The downside is that an Alpha-n fueling profile is less accurate at part-throttle and towards idle speeds.

An Alpha-n fueling profile does not generally utilize a closed loop mode (O2 sensor) for air-fuel correction. An EFI component change, and change to engine components will generally result in a complete engine tune adjustment to suit.

MAF Fueling

The mass air flow (MAF) sensor is located in the air inlet to the throttle body and directly measures the amount of air going into the engine.

The most common design is the hot wire design. Air flows past a heated wire that measures the electrical current in the circuit. The heated wire is used to keep the inlet air temperature at a temperature that is always just above the ambient air temperature by a fixed amount. The MAF sensor sends a signal to the ECU and the ECU determines the mass flow based on the signal voltage. Once the ECU has determined the amount of air entering the engine, it correlates this reading with the other engine sensors to determine the fueling requirements according to the ECU mapping.
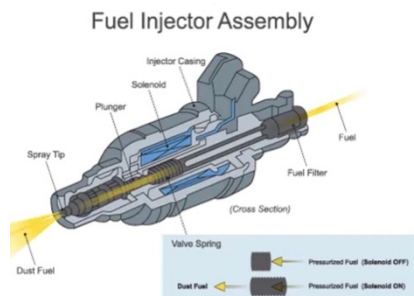
A MAF fueling profile is not very practical on motorcycles due to space constraints. The next best option is a speed-density fueling profile, followed by an alpha-n fueling profile. There are pros and cons for each, and which system you choose will be based on your project requirements.

Fuel Injectors

The fuel injector has a lot of different issues that need to be understood compared to most EFI components.

The main reason for the ECU as mentioned, is to take the various EFI sensor inputs, apply these to the ECU engine programming, and determine the correct amount of fuel required to be delivered to the engine for optimal engine operation at all power levels. In simpler terms, take all the sensor inputs, browse through the myriad of ECU tables and settings, determine the correct air-fuel mixture, and deliver the fuel to the engine by way of the fuel injector.

A fuel injector is nothing more than a high-speed valve for the delivery of fuel to the engine. Electrical power is supplied to the fuel injector whenever the ignition key is turned to the ON position. The ECU controls the operation of the fuel injector by providing the fuel injector power circuit with a ground, completing the fuel injector circuit, allowing current to flow through the injector, energizing the fuel injector so that fuel flows through the injector and into the engine. Conversely when the ECU removes the ground path for the fuel injector power circuit, the fuel injector is deenergized and the pintle that was moved off its seat is pushed onto the seat by a spring internal to the fuel injector. This shuts off the fuel flow to the cylinder.

Fuel Injector Assembly

Injector Casing
Solenoid
Plunger
Spray Tip
Fuel
Fuel Filter
Dust Fuel
(Cross Section)
Valve Spring
Pressurized Fuel (Solenoid OFF)
Dust Fuel
Pressurized Fuel (Solenoid ON)

Fuel Injector Internal Components

The fuel injector being the small mechanical component that it is, is extremely important to the engine operation.

The fuel injector importance in an EFI system is up there next to the ECU, and crank and/or camshaft sensors used for engine timing and ignition.

Fuel injectors are classified as either high-impedance (saturated), or low-impedance (peak and hold) fuel injectors. High-impedance fuel injectors have an impedance range of approximately 9 to 14 OHMs. Low-impedance fuel injectors have an impedance range of approximately 1 to 5 OHMs. Most modern EFI systems are designed using high-impedance fuel injectors because the fuel injector circuit requires current flow to be limited to approximately 2.5 amps or less. Low-impedance fuel injectors can be used; however, each fuel injector circuit requires an in-line resistor that in combination with the fuel injector resistance, reduces current flow in the fuel injector circuit to 2.5 amps or less.

It is necessary to have and to know the fuel injector design data, and enter this data in the tuning software for the ECU to use. If this information is not available, it can be determined through experimentation. To do this, there is a good amount of information available on the internet and in the various ECU, motorcycle and automotive forums to assist you.

If time is not your friend, then it may be easier and faster to use a company specializing in fuel injector cleaning, flow and leak testing that provides fuel injector performance data for the fuel injector to be used.

How the ECU uses the injector data is quite remarkable. We don't see it, we don't hear it, we just accept that it is being done. Only when something goes awry do we pay attention, maybe.

Every sensor input and setting in the ECU programming is needed so that you can properly tune the EFI system for correct engine operation.

The amount of time a fuel injector is turned on and delivering fuel to the engine is called the fuel injector pulse width. It is the time required to have fuel flowing into an engine cylinder based on all the parameters, sensor inputs and settings that you have entered into the tuning software, and to open and close the fuel injector.

When the engine needs more fuel such as during acceleration and at cruising speeds, the base pulse width increases and the fuel supplied to the engine increases.

Fuel injectors have what is called a duty cycle. This is a percentage of the fuel injector fuel flow rate capacity. The industry standard is approximately 85 percent. It means that if a fuel injector can flow approximately 300 cc/min at standard test pressure of 3 bar (43 PSI), then the accepted maximum fuel flow rate for the EFI system design should be approximately 255 cc/min at the EFI system design fuel pressure. This ensures that there will be enough fuel delivered to the engine during all operating scenarios.

Having the base fuel injector duty cycle at approximately 80 to 85 percent ensures that there is room for an increase in duty cycle from this base percentage should additional fuel be required up to and including full engine power, and will not starve the engine for fuel.

Adjusting the fuel injector duty cycle and characteristics, the engine fuel requirements, changing fuel injectors for larger - smaller flow rate fuel injectors, and such will probably result in having to revisit the engine tune and adjust accordingly. If this is not done, engine performance can be affected.

Another term that is mentioned is when a fuel injector is permanently energized in the open position of 100%, the fuel injector is deemed to be "static". If a fuel injector is "static", the ECU is no longer able to control the fuel injector and deliver the correct amount of fuel to the cylinder in question.

Injectors have a static flow rate determined on manufacture. This is the flow rate of the fuel injector at a 100% duty cycle, permanently open, and at a standard test pressure of 3 bar (43 PSI). This flow rate can be in cc/min or lb/hr.

There may be times when the injector pulse width will increase for what may seem to be an unknown reason.   This generally happens when the fuel injector becomes restricted or blocked. The ECU will attempt to compensate for this by increasing the fuel injector open time (pulse width) adding more fuel to the engine.

Using larger than needed fuel injectors can be advantageous, but for most installations, these larger fuel injectors can be problematic. Most people who change their engine fuel injectors hope for an increase in engine performance, but without a retune of the ECU settings-parameters, this probably will not happen.

Fuel injectors as mentioned, are open for a specific amount of time for a specific operating profile. The fuel injector does input a sensor signal to the ECU, and as such, is not an EFI component that the ECU has to consider, but the ECU does affect the fuel injector.

Larger fuel injectors may contribute to a rough, uneven idle, could cause a misfire, and affect fuel economy. This will be manifested in the engine operating in a fuel rich condition at all times. Conversely, a smaller flow rated fuel injector may perform well in the lower power range(s) and at idle, but when operating in the higher power ranges, the engine can be in a lean fuel condition.

Fuel Injector Location

The location of the fuel injector is something that should be considered for optimal engine performance. There are many considerations such as space requirements, and what type of fuel injection profile to be used. If you are modifying an existing EFI installation, this work has been done for you.

This design consideration is important when you are doing an EFI conversion project and you are determining how to mount the fuel injectors – what to use, and where to mount the fuel injectors.

The modern-day industry standard is to orient the fuel injector(s) so the fuel injector fuel spray is directed at the engine cylinder intake valve. How you orient the fuel injectors to accomplish this may also affect your decision as to what type and style of fuel injector, and fuel injector holder you use.

The available options are port and throttle body fuel injection, and direct fuel injection. Direct fuel injection is too specialized and will not be discussed.

Port fuel injection is the easiest way to ensure that the fuel injector is oriented to spray directly at the base of the intake valve. Using port fuel injection because the fuel injector spray is directed at the base of the cylinder intake valve assists fuel atomization during cold start and normal operation because the cylinder intake valve heats up faster than other cylinder components. There is less wall-wetting, fuel puddling with this type of fuel injection.

Another benefit of this design is that during normal waste spark engine operation, fuel sprayed at the cylinder that is on the exhaust stroke will atomize and not be "sitting" around waiting for the next squirt during the cylinder compression-intake stroke.

Throttle body fuel injection is very common in motorcycle EFI systems. This type of fuel injection system is used just as much as port fuel injection. The main difference is the distance fuel has to travel to get to the engine cylinder and the challenges associated with this such as increased wall-wetting, fuel puddling.

I do not advocate becoming a design engineer regarding this, but that you understand the differences between port and throttle body fuel injection and then, as always, make an informed decision.

Fuel Injector Spray Tip

The fuel injector spray tip type and location are important for fuel delivery. Manufacturers spend a significant amount of resources to get the fuel to the right place at the right time.

To minimize fuel puddling/wall wetting, the OEM locates the fuel injector so that it sprays directly at the intake valve. The intake valve warms/heats up the quickest and spraying the fuel at the intake valve because of this, aids in fuel vapourization.

The CFI system fuel injectors are a "pintle" style fuel injector, and spray fuel from a single orifice nozzle directly at the engine cylinder intake valve. The other spray tip configuration used is the "disc" type.

The pintle style fuel injector may have a more direct spray such that the injector fuel spray can be "aimed" at the target area.

A disc style fuel injector can have a single, or multiple hole spray pattern.

The fuel injector spray pattern can be advantageous especially in throttle body fuel injection systems. Getting the fuel as far down the intake runner as possible, keeping the fuel away from the intake runner wall for as long as possible may reduce wall-wetting, fuel puddling.

The fuel injector spray tip has also been chosen for its length, how far into the air flow does the spray tip extend. This aids in getting the fuel injected into the air stream at the optimum location in accordance with the OEM design, drawing the fuel to the designed location, and minimizing fuel puddling.

Fuel Puddling – Wall-Wetting

Manufacturers have been agonizing over this issue for years and still are.

Port or throttle body fuel injection are considerations as is direct engine cylinder fuel injection. Port injection can minimize this issue by spraying directly at the engine cylinder intake valve, minimizing wall-wetting, fuel puddling. Throttle body fuel injection allows for more wetted surface area and as such, the amount of wall-wetting, fuel puddling is generally more.

Direct fuel injection sprays fuel directly into the engine cylinder after the intake valve. This is the most efficient way to get fuel into the engine cylinder for use. This design is becoming the norm with most automobiles. The one downside to this type of fuel injection is the cleanliness of the intake valves. Spraying fuel into the intake system before the engine cylinder has the effect of "washing" the seating area of the intake valve and the intake valve itself. Anyone who has had a cylinder head off and apart has probably noticed the intake valve(s) are cleaner than the exhaust valve(s)

Until the motorcycle world catches up, historically the motorcycle world follows the automotive industry, port and throttle body fuel injection will be the mainstay of the motorcycle EFI world, especially the DIY EFI world.

Wall-wetting, fuel puddling happens in all engine intake systems that are not direct fuel injection. The amount of fuel puddling depends on where the fuel is injected into the engine intake system, and is deemed to be constant for that design. Fuel puddling reduces or increases depending on the air flow in the engine intake system.

This change in fuel puddling and the amount of fuel puddling may be a very important consideration in high performance and racing applications, it is not so important for normal street use, just need to understand that it happens.

This wall-wetting, fuel puddling assists in engine performance in that it provides additional amounts of fuel into the engine cylinders during periods of normal engine acceleration. The increased air flow over the fuel puddle draws fuel from the puddle reducing the fuel puddle amount. This fuel from the fuel puddle is not significant enough to change the ECU calculated air-fuel mixture requirement.

Once the ECU catches up with the increased engine fueling demand, the fuel puddle amount is then replenished because the design consideration is that the fuel puddle remains constant throughout the operation of the engine.

Acceleration enrichment (AE) affects fuel puddling. During times of rapid changes such as when the throttle is snapped open quickly, for a long or short period of time, fuel puddling will be reduced quickly. The increased air flow into the engine causes the engine to temporarily operate in a fuel lean condition because there is not enough fuel picked up from the fuel puddle by the increased air flow to compensate for this fuel lean condition that can result in a potential loss of power followed by a sudden surge back to where the engine should be.

Enter acceleration enrichment. AE compensates for this lack of fuel and aids in maintaining a smooth engine operation during periods of sudden change.

Deceleration, when the throttle is closed quickly, or partially, fuel may need to be temporarily switched off to make sure the fuel puddle is maintained. Less air flow across the fuel puddle, the less the fuel puddle reduces, and when the throttle is opened/adjusted for the new driving condition, fuel will need to be reintroduced to ensure the engine will not operate in a lean condition.

Dead Time-Injector Latency

Fuel injector dead time-injector latency, is a combination of the opening and closing times of the fuel injector when no fuel is spraying from the fuel injector(s).

When the fuel injector is required to open, there is a lag between the ECU signal and when fuel starts to flow into the engine cylinder. This is because it takes time to energize the fuel injector internal coil that raises the fuel injector pintle off the spray tip pintle seat, and overcoming the internal spring that is forcing the pintle onto the pintle seat (an internal spring applies pressure to this pintle and keeps the pintle in the closed position).

When the ECU fuel injector ECU signal is stopped, the fuel injector will close and fuel will no longer be flowing into the engine cylinder. This takes time as the fuel injector internal coil has to dissipate the magnetism in the internal coil and as this is done, the pintle is pushed down onto the pintle seat and fuel flow is stopped. A very small amount of fuel continues to be delivered to the engine intake manifold during the closing of the fuel injector, but not enough to make any difference to engine operation.

Injector dead time-injector latency data needs to be accurately input into the ECU programming software. It is an easy process if the fuel injector data is provided. Unfortunately, this is not always the case.

Most new DIY EFI installations use fuel injectors that have no data available other than the fuel injector flow data at a 100% duty cycle and with a test pressure of 3 bar (43 PSI). This will require you to determine the fuel injector dead times through experimentation. A fuel injector dead time-injector latency time of 1.0 ms to start is an accepted norm. This is presuming that you have had the fuel injectors of choice cleaned, flow and leak tested.

Most will accept information found in the various forums for the fuel injector of choice. The downside to this approach is that the fuel injector(s) may or may not flow at this specified flow rate.

Several factors make the dead time-injector latency determination somewhat complicated, and time consuming.

The fuel injector opening time is not linear. It is a curved line that makes it difficult to extrapolate definitive numbers. The fuel injector closing time is similar. Electrical system voltage has an effect, varying voltages influence the fuel injector operation. Fuel pressure is an issue. Fuel pressure differential across the fuel injector could change, the FPR could malfunction or not be maintaining the correct fuel system pressure. These are a few of the considerations you need to be aware of, there may be more.

There are many ways to do initial fuel injector tuning. A wealth of information can be found on the internet and various on-line forums.

A recommended approach is to not touch the VE table, but to adjust the fuel injector flow rate and fuel injector dead time-injector latency until the AFR is close to what is expected. Then adjust the VE table to suit.

Given that you have a set of fuel injectors in good condition, cleaned, flow and leak tested, you can adjust the Required Fuel (RF) setting and the fuel injector open time to get the initial AFR setting close to what is required.

Most DIY tuning aficionados recommend adjusting the VE table first, then moving on to the finer details. Whichever initial tuning scenario you choose, research it and learn what it entails.

Approximating Fuel Injector Fuel Flow Rate

Approximating initial fuel injector flow rate should be avoided if at all possible. This flow rate is used by the ECU tuning software to determine the Required Fuel (RF) calibration, and impacts on the amount of fuel that will be injected into the engine for operation.

Many use fuel injectors that have been around for a while, but the state of the injector(s) is unknown. You should have the fuel injectors of choice cleaned, flow and leak tested as a minimum before use.

Not having this basic maintenance done can have engine tuning issues that never seem to get better such as spark plug fouling, poor fuel economy, lack of power when on the street to name a few. There are probably more issues that can happen, but suffice it to say, fuel injectors in good condition, and knowing the actual fuel injector flow rate maximizes your chance for success.

Fuel Injector Voltage Compensation

The fuel injector pulse width is affected by the electrical system voltage. Most modern-day vehicles, motorcycles included, operate with an electrical system voltage of approximately 14.2 VDC. This is the alternator reference voltage. This voltage changes with engine load, what ancillaries-accessories are being used, how good is the battery state of charge, what is the internal health of the battery to name a few.

Operating at approximately 14.2 VDC ensures that the fuel injector pulse width is optimal for engine operation and fuel will be delivered within this given time for all engine operating scenarios.

When the electrical system voltage increases or decreases for whatever reason, the fuel injector pulse width may be adjusted by the ECU to deliver the required fuel quantity to the engine. The ECU uses the Injector Voltage Correction table to apply a fuel injector pulse width percentage correction to the entire fuel injector pulse width, or just the fuel injector open time.

To adjust the Injector Voltage Correction table, use a variable DC power supply. This allows you to vary the fuel injector voltage with the engine operating and observe the results of this with your tuning software.

You could reduce the amount of electrical system voltage by disconnecting the alternator from the electrical system, record the electrical system voltage reading and determine the affect this has on the fuel injector. Doing this will give you two reference points from which to extrapolate a fuel injector voltage compensation curve. The disadvantage to doing this is that you are impacting the operation of the EFI and other operating systems.

EFI systems are extremely dependant on electrical system voltage, more so than a similar carbureted model. Reduced electrical system voltage to the EFI system, specifically the fuel injector(s) can result in engine misfires, stumbles, excessive fuel smell out the exhaust and a myriad of other issues that can be misdiagnosed.

When tuning for a specific parameter or set of parameters, it's always best to determine a test procedure that addresses the requirement without affecting other parameters-settings, or other non-EFI operating systems.

Throttle Position Sensor (TPS)

I have discussed these little items previously, but want to bring it all together in this discussion.

It's a three-wire potentiometer with a 5 VDC input voltage and the TPS outputs to the ECU a signal voltage of 0 to 5 VDC depending on the throttle position. It is used to signal to the ECU the throttle position from closed to fully open. It is used for the engine load parameter for an Alpha-N fueling profile.

Simple right?

There are considerations when dealing with a TPS.

Is it a contact/non-contact TPS. What this means is that for a contact TPS, the internal components are in contact, and wear over time is an issue. A non-contact TPS is generally but not always a hall effect sensor and the internal parts do not come in contact with another internal part. The non-contact type TPS is generally more expensive.

What way does the TPS rotate? Clockwise or counter clockwise.

How far does the signal arm rotate? The signal arm should rotate the same amount as the throttle plate shaft, maybe slightly more. Having a TPS sensor arm not rotating the required number of degrees, reduces the voltage signal to the ECU, skewing the ECU operation.

A TPS can have, but not be limited to, a 90°/120°/180° rotation. If you have a requirement for a TPS that needs to rotate 90 degrees, but you are using one that rotates 180 degrees, you very well could have an engine performance issue.

How do you calibrate the installed TPS to work with the EFI system? I have perused the internet and such, and have not found information specifically related to TPS setup with an EFI system unless the EFI system is factory installed. This calibration will have to be determined through experimentation.

Where is the TPS going to be installed?

There are no new OEM TPS units available for the early model Gold Wing FI motorcycles. This requires a person to fit an aftermarket automotive TPS. There may be other manufacturer TPS that could be used, but the most used alternative is a TPS sensor from an early model Honda Civic/Prelude.

This TPS can be installed without too much trouble with the exception that the TPS sensor arm must be modified to connect with the throttle plate shaft.

The installation of an automotive alternator in lieu of the traditional 3-part alternator (rotor, stator, external regulator-rectifier) makes the installation of an aftermarket TPS a challenge because of space requirements. The alternator is generally installed immediately beside the original TPS.

The wiring for the new TPS is well documented in the various internet forums and search pages.

A new aftermarket TPS may or may not be faulty. These are inexpensive units and are not subject to rigorous quality control standards. A new aftermarket TPS can be faulty from the get go, or not. It is recommended to have a couple of spares available just in case.

When a TPS is faulty, it can affect engine timing, fuelling and of course, engine operation. Heat also affects these units. A TPS unit can be faulty in a very specific engine operating range, but above or below this range, work well.

When a TPS is faulty in a specific engine operating range, the ECU may or may not generate an error code. If an error code is generated because the TPS is faulty, troubleshooting is relatively easy. If there is no error code, troubleshooting the issue becomes more challenging. Is the issue based on fuel, ignition or CFI problems.

Replacing the TPS requires you to remove the OEM break-off/shear bolts that are installed at the factory. You will need to remove these bolts. Using a Dremel tool, grind a slot in the top of the bolt and remove with a screwdriver.

Coils

The coils used in the CFI system have a primary coil resistance are 2.4 to 3 OHM and a secondary resistance of approximately 19K OHMs (spark plug wires attached – plug caps removed). These coils are quite robust, and last a long time. The Honda OEM service manual indicates that these coils are not polarity dependent.

Coils are generally designed to operate with a specific ignition module - coil driver, and EFI system. This may not always be the case because we have the fantastic habit of changing things to make what we own ours, and because we are inquisitive types.

Coils that are used in a factory EFI system are going to work fine for a long time and over the entire engine performance range.

This changes as the engine operating system and parameters change.

Coil upgrades can be beneficial, but not so much for a slower revving engine. Higher revving engines benefit because at the higher RPM ranges, the dwell time becomes so small that a standard coil reaches a dwell time that does not allow for the coil to charge - discharge, and keep up with the requirement. This can result in engine misfires, loss of power and the likes.

Dwell Time

Dwell time is the amount of time required to fully charge the coil so that when it discharges through the spark plug, the spark created for combustion is powerful enough to ensure complete combustion as per design. Too little dwell time and the spark will not be as powerful as it should be, too great a dwell time and you have the potential to "fry" the coil, coil driver - ignition module, or both.

The ignition coil design is such that the designed coil dwell time provides the required coil charge for the designed engine ignition event.

The size of the wire used for the winding, the number of turns of the primary coil and the input current determine the amount of coil charge that will be developed prior to an ignition event.

Once the input current is stopped and the coil magnetic field collapses, the coil charge is transferred to the secondary coil and then through the spark plugs for the ignition event.

The turns ratio between the primary and secondary coils defines the "step up" of the coil charge for the ignition event.

Having mentioned the above, not all ignition coils are created equal, as with most other components. An ignition coil may have the same primary and secondary coil resistances, but not have the same turns ratio, or size of wire required. This may not be an issue for us and many others when it comes to street use, but can be an issue for high performance and race engines.

This is where the ignition coil data is required. Depending on the coil manufacture, depends on what ignition coil data you will be provided with. If the ignition coil data is comprehensive, experimentation and/or calculating the ignition coil data will not be required. If the ignition coil data is sparse, you will have to resort to experimentation and/or calculations.

If you do not have the coil data necessary to provide the dwell characteristics of the coils you are using (similar to fuel injectors), Matt Cramer and Jerry Hoffman in their book Performance Fuel Injection Systems provide procedures you may want to use.

Hot Finger Method

This is a procedure where you monitor the coil temperature and set the dwell time. You have one finger on the coil to monitor the coil temperature (very scientific).

You lower the dwell time in small increments until the engine starts to stumble and/or misfires. Raise the dwell time until the engine stumble and/or misfire goes away and the engine has "smoothed" out. Do this is small increments as well. Check engine performance at idle and on the street if possible. Continue doing this procedure until your engine is firing well.
Once you have the coil dwell set, raise the coil dwell in small increments until the engine starts to stumble and/or misfire. When doing this part of the procedure monitor the coil temperature so as to not overheat the coils. When the engine performance degrades, reverse the coil dwell setting until the engine "smooths" out. Check engine performance at idle and on the street if possible.

Since you have been taking notes, compare the two dwell settings. If there is a dwell delta, a slight spread between the two dwell settings, adjust the coil dwell in small increments and trial each change until you have optimized the coil dwell for your application.

As mentioned, monitor the coil temperature of the coil using your fingers during this process. The coil "hot finger" temperature should be at or just above room temperature.

Oscilloscope Method

This is a preferred method instead of the "hot finger" method. Use the oscilloscope to measure the current flowing into the coil. Current flow will fluctuate as the coil charges/discharges. Set the dwell time so that it is just less than the maximum current rating of the primary coil, or the coil driver – whichever is less.

If this current level cannot be determined, you can use a "current limiting" setting. Using the oscilloscope, determine the level at which the current levels off and set the dwell time so that the current limiting that will be used is slightly less than the maximum current limit displayed by the oscilloscope. You need to do this, or you have the probability of "frying" your coil(s).

If possible, determine the coil maximum primary current.

Calculator Method

Having the coil inductance of the primary coil circuit, and the resistance of the primary coil circuit, you can calculate the dwell required. You will need a scientific calculator that has the logarithm (ln) function.

The formula to be used is:

Dwell Time = (coil inductance ÷ coil resistance) x ln [1 – (coil resistance x maximum coil current) ÷ (maximum alternator voltage)]

Coil inductance can be calculated using the values from the oscilloscope.

The formula is: L = V * Ton ÷ Lpk

L – Inductance
V – Voltage delivered by the pulses
Ton – Time between pulses
lpk – peak current measured
The alternator voltage that you should use should be ~14.2 VDC, alternator reference voltage.

A motorcycle alternator is generally a three-part alternator with an external regulator/rectifier, and internal engine rotor and stator, still with a reference voltage of ~14.2 VDC.

Spark Units (Coil Drivers - Ignition Module)

These CFI spark units have stood the test of time and are very reliable. The issue is there have been no alternative coil drivers identified as a replacement.

Spark units (coil drivers - ignition modules) can be either "smart" or "dumb" units. It is not known which the CFI spark units are, but suffice it to say a good guess would be that these are "dumb" ignition modules probably from an economic point of view.

My research into coil drivers indicates that the CFI spark units may be able to be replaced with a more modern "dumb" coil driver. What needs to be determined is what signal the ECU provides to the coil driver to activate it.

The ECU may send a small current - voltage to the dumb ignition module, or provide a grounding signal to turn the ignition module on. Removing the voltage signal causing the voltage signal to drop to "0" and cause the ignition module to fire the coils, as will removing the ground and the voltage at the transistor goes back up.

Smart ignition modules generally receive a simple digital square wave from the ECU that is ON/OFF for an equal amount of time. You need to know when these ignition modules fire the coils through the spark plugs, when the voltage signal is ON or OFF.

The disadvantage to using a smart ignition module is, that these generally work well in an EFI system designed for these. Smart ignition modules have preprogramed dwell times and specific current requirements, and generally need to be matched to a coil, or coil set(s) that have a current draw and dwell time that matches the ignition module. Using a smart ignition module that controls the coil dwell time and pairing it with a coil that may need considerably less dwell time can "fry" the coil, ignition module or both.

A dumb coil driver - ignition module may be used with a coil not designed specifically to be used with it, but you can adjust the coil dwell time using the ECU program, minimizing and sometimes eliminating operating issues.

How the ignition module is switched ON/OFF by the ECU must be determined. This is generally known as GOING HIGH or GOING LOW. GOING HIGH or GOING LOW for an ECU may be the opposite for a different ECU. In other words, GOING HIGH may mean GOING LOW for a different ECU.

The coil drivers available for use with an aftermarket ECU are well documented as are the coil driver settings that you enter into the ECU tuning software.

Ignition Systems

There is a plethora of used and aftermarket ignition systems for you to use. The CFI ignition system is comparable to all EFI systems, and there should be few, if any surprises.

The CFI system is fairly basic when it comes to the ignition system, has coils, spark units (coil drivers – ignition modules), uses a crank and camshaft trigger wheels. Has a TPS and fuel injectors. As mentioned, nothing earth shattering.

The CFI system uses a combined crank and camshaft trigger wheel setup, as to what it is called, is not known. The new ECU that I am going to use calls this type of trigger wheel (decoder wheel) setup a "dual wheel" setup. The alternative is a missing tooth trigger wheel setup that does not use a second rotational input to the ECU.

With the amount of ignition system and ignition system component options available to you for use with an EFI system, care must be taken to ensure that the ignition system chosen is compatible with your choice.

You need to determine as has been mentioned, whether your coil driver - ignition module charges the coil when the voltage goes from low to high and the coil discharges when the voltage goes from high to low. Most ignition modules follow this charging/discharging profile. There are some ignition modules that charge the coil when the input signal is grounded, and discharge the coil when the ground is removed. Current flow is the same through the coil, but how it is controlled is the issue.

The ignition module trigger edge is of importance regarding the timing of the cylinder spark. This is called a RISING EDGE, or TRAILING EDGE setting. When the ignition module charges on the rising edge of the signal, you generally use the falling edge of the trigger wheel to signal a coil firing requirement. When you charge the coil with a falling ECU signal, you generally fire the spark on the rising edge of the trigger wheel.

It would seem that the GOING HIGH/LOW and RISING/FALLING EDGE ECU settings are interrelated. These two settings must be input correctly.

Fuel System

Not a lot to add to what has been mentioned earlier; however, how the fuel system performs should be of interest.

I have mentioned that the fuel system is a high flow and pressure fuel system. This is accomplished by using a high flow/pressure fuel pump and a fuel pressure regulating (FPR) valve.

The fuel system should maintain all, if not some of the system fuel pressure for a reasonable amount of time. When the fuel system reduces in pressure to "0", air is allowed to enter the fuel system fuel injector fuel rail. This air needs to be expelled from the fuel rail, and to do this, the air will either flow through the FPR valve back to the fuel tank, or through the fuel injectors.

If the air is expelled through the fuel injectors, there may/will be an engine start issue. Once the air is out of the injector fuel rail, the engine will operate as it was meant to.

CONSIDERATIONS

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EFI System Preparation

There is a lot to consider at this stage in the EFI process. If you have been reading this document to get an idea and understanding of an EFI system, or to determine if an EFI system is in your future, hopefully this document has been helpful.

The information herein is my understanding of what an EFI system is, what it can do, how it does it, the different interactions between the sensor inputs/outputs, what the terminology means and how everything rolls up an becomes an EFI system.

I thought I had the CFI system operation and component interrelationships well understood; however, since I started my CFI system ECU upgrade/replacement project, I have learned so much more.

I started my CFI system ECU replacement/upgrade project some time ago. It is not uncommon to read about an EFI project and seeing that the time spent on the project has been a year or more.

The Difference

Most of us that own these 1985/1986 Gold Wing FI models become very familiar with how the systems and components work. We are confident in our knowledge of how to maintain and troubleshoot the CFI system. We are capable of changing components, and calibrating these as needed.

Fast forward this understanding to a CFI system upgrade such as the CFI system ECU replacement/upgrade project I am doing.

Many questions will be asked by yourself. You will try to correlate and use the Honda CFI system operating parameters to the new project.

Understanding, using and maintaining the CFI system as installed if you are not going to upgrade/modify the CFI system is all you nee to know.

It was recommended in the ECU forum that I am on, that I must leave the Honda CFI world behind and go forward as if this were a new build. Trying to use the design philosophy and CFI system settings when upgrading the CFI

system confuses the issue, and makes it harder to move forward with the project. The only similarity is that the EFI system components are already installed.

I have asked myself many questions about the "why" of an issue and how to use this issue with the new ECU.

Honda has the 1500/1800 idling at approximately 900 RPM. Is this because Honda changed from a stator application to an alternator charging system? Is the 1200 idle at 1000 RPM +/- 100 RPM because of the stator? I have installed an external alternator and as such, should be able to idle the engine successfully at 900 RPM (will also get rid of that hard "thud" when you go from neutral into fist gear) because Honda designed the GL1200 engine as if it were an automotive flat-4 boxer engine.

There is no TPS calibration procedure for this upgrade/modification, and will need some calibration experimentation before this project is finished.

Engine ignition timing is easy to set for these engines. You use the crankshaft "T1" mark for #1-cylinder TDC, align the timing belt camshaft pulleys to match, and all is good. You do not have to check/set the timing using the "F1" crankshaft mark at idle. You do have to do this when you are upgrading the CFI system with new components.

The reality is that you must abandon the CFI system concepts and how the CFI system works as installed. You must look at the project with a new perspective.

CFI System Upgrades/Changes

The first issue to be resolved was that of the loss of fuel system pressure when the engine is not started. I have researched this and discussed it with some who have done an automotive EFI project, and have received mixed response and reviews.

There are three components that can make this happen. Fuel injectors, fuel pump, and fuel pressure regulating (FPR) valve.

The fuel injectors had been cleaned, flow and leak tested and should be in good condition. This was the first component considered to not be part of the issue.

The injectors were removed, fuel rail connections blanked off, and the FPR valve and fuel pump tested.

I determined that the fuel pump was not maintaining fuel system fuel pressure by disconnecting the FPR valve from the fuel tank – no fuel could flow back to the tank. The fuel pump internal non-return valve was not working.

The FPR was removed and bench tested. The FPR valve maintained a pressure of 36 PSI and was ruled out as a possibly failed part.

Having all this information, I decided to upgrade/modernize the fuel system.

New fuel lines have been installed using Army-Navy (AN) and O-Ring Boss (ORB) fittings. These fitting are quite good, and reusable.

A new in-line fuel filter and non-return valve has been installed, tested and there is no more fuel leaking back through the fuel pump.

The original FPR valve has been replaced with an adjustable FPR valve. This has been done because the CFI system fuel pressure that is used for the CFI system, is not adequate for the CFI system with the new aftermarket ECU installed.

The fuel system pressure for the upgraded CFI system will be an operating pressure of 36 PSI using the original 280 cc/min low impedance fuel injectors. 280 cc/min is what the fuel injectors flow at a pressure of 43 PSI. With an 85% duty cycle and fuel pressure reduction to 36 PSI, the new fuel injector flow rate will be 217 cc/min. This is compared to 198 cc/min using the OEM CFI requirement. I will be able to better define and maintain the intended fuel pressure with an adjustable FPR valve.

Fuel system pressure has been determined from a lot of research and reading about real world use. The same has been done regarding the fuel injectors, the size (using the original fuel injectors), and how the fuel injectors should work using the fuel system pressure chosen. The fact that you can, with the new ECU, tune the engine for proper air-fuel mixture and AFR value, makes using a specific size of fuel injector that much easier.

Fuel injector data that is not available for the OEM CFI system fuel injectors has been considered. It is possible to determine what this data through experimentation. The better way is to have the fuel injectors sent to a facility that can clean, flow and leak test the fuel injectors as well as determine the fuel injector specifications – data, for use with the new ECU. The injectors that will be used have been sent to such a facility to be overhauled and fuel injector data ascertained.

The CFI spark units have been replaced with a Bosch 211 coil driver that is capable of controlling up to 4 coils and ignition circuits. The settings for this coil driver are GOING LOW and the trigger edge is set at a RISING EDGE.

The OEM coils have been replaced with a new aftermarket coil pack used in the Opal-Corsa ignition system. These coils will work, but retrofitting these into the same space as the OEM coils is not an easy task. The OEM coils will work and have been working with this new ECU, and coil driver. Using the OEM coils will probably be the best option as the project progresses because of space limitations for an aftermarket coil install.

The spark plugs wires and spark plug caps have been changed. I have been using copper core spark plug wires instead of steel core wires and have removed the resistors in the spark plug caps. The resistors have been replaced with solid copper core wire (#10 GA). This is in-line with the automotive industry that uses suppression style spark plug wires and resistor spark plugs. The automotive industry does not use resistor style spark plug caps.

The CFI system crank trigger wheel has been replaced with a missing tooth trigger wheel, a 36-1 trigger wheel, generally accepted as the go-to crank trigger wheel when a second trigger wheel is not required, and doing some form of an EFI project.

The camshaft sensors have been removed. These will not be used, and shall remain disconnected and possibly removed entirely.
I will be investigating the dual wheel decoder system and may revert to it. This is using a crank and cam trigger wheel system.

A wide band oxygen sensor (WBO2) has been installed to assist in normal engine operation and engine tuning.

The vacuum system has four vacuum ports, one for each of the engine cylinders, that are used in the CFI system. These vacuum ports have been connected to a vacuum mixing chamber, and a single hose goes from the vacuum mixing chamber to the ECU.

A follow-on upgrade will be to install a real time barometric sensor.

Engine timing has been finalized and set. Cylinder spark has been confirmed.

Wiring

A discussion on wiring needs to be had, and connecting the OEM wiring harness to the new ECU directly affects this.

The OEM wiring harness can be used with very little modification.

1985/1986 Honda Gold Wing GL1200 Computerized Fuel Injected Models – 19 June 2023

You will have to decide where the new ECU is going to be placed. There is very little space on the 1985/1986 FI models for the new ECU to be located. You can use the existing CFI system ECU location, rear trunk, saddlebags, or the front fairing.

I have chosen to install the new ECU in the same place as the original CFI system ECU, under the rear trunk. It is dry, and has good air flow for ECU cooling.

I will be using a CFI system ECU enclosure to house the new ECU. This enclosure needed some modification to accommodate the new ECU. The new ECU is smaller, and requires a connector to connect to the OEM wiring harness. There are connectors available on-line that are the same as that that the OEM used. The ECU enclosure I am using is an OEM CFI system ECU that had a ground circuit fault and the ECU had failed.

If you do not use a similar process, you will need to source a suitable connector, remove the required pins/wires from the OEM wiring harness connector, and mate all the various pins/wires. A second consideration is that if you were to revert back to the OEM CFI system for whatever reason, using the OEM wiring and ECU connectors will allow you to change back to the OEM configuration. Changing to a different wiring harness and ECU connector will require you to remove the different wiring harness and ECU connector and reinstall the original wiring harness and ECU connectors.

OEM CFI System ECU and New ECU Input/Output Pin Collation

You can find a CFI system pinout schematic on the various forums. From this, you can marry the various sensor, component pin numbers with the new ECU pinout chart.
I have a few changes being made to the CFI system pinout chart on the ECU connector side that if I decide to revert back to the OEM CFI system in its entirety, I will be able to.

There are a few changes to the CFI system wiring to accommodate existing and new installs.

I have used one of the PB sensor ECU connections for the O2 sensor input to the new ECU. This has been done by splicing into the PB wiring. I will be using the second PB sensor as a barometric sensor.

The pinout for the VR conditioning board is not as intuitive as one might think. There is a crank and cam sensor input for these sensors. The VR1+ for the crank and VR2+ for the cam sensor is self-explanatory, but where to connect the "-" wire is not. There are a lot of grounds available for use, and you might be inclined to use one of these for the crank and/or cam. You must use the VR1- for the crank sensor and VR2- for the cam sensor.

If you are using a Hall Effect sensor for either the crank or cam sensor(s), you connect to the VR1+ or VR2+ only, bypassing the VR conditioning board.

The easiest way to solve this wiring issue is to determine if you need a second rotational input, and if not, use the appropriate missing tooth trigger wheel, crank or cam, and use the appropriate pin connections.

The CFI system fuel pump uses a fuel pump relay that is controlled by the ECU. Most aftermarket ECUs do not have a dedicated fuel pump relay pin connection for the grounding circuit, some do. If the ECU of choice does not have a dedicated fuel pump ground circuit for the fuel pump relay, there should be a work around for the ECU of choice that you can do.

The use of a real time barometric sensor is of benefit to the engine operation especially if you intend to travel through mountainous areas.

There may be a MAP sensor already installed on the ECU interface board of choice, or not. If so, you can use this MAP sensor as the load sensor for the engine fueling requirement, Speed Density (SD) fueling, or you can use an external MAP sensor for this.

If you use an external sensor as the MAP or barometric input, you will have to put together a MAP/barometric sensor circuit to use. There is information and schematics on the various forums related to this.

You may want to install a Bluetooth unit. There is a lot of information regarding this, research what you want to do, understand the limitations, and put in place.

Creating the initial Engine Tune in the Tuning Software

The next step that was done quite a while ago, was to populate the new ECU tuning software with the known and generic settings to start the tuning process. There are accepted norms, setting approximations that will assist you in preparing your initial engine tune.

Once the FI system components have been decided on and installed, and with the initial engine tune complete, you are now ready to go to the next step, that of an engine start and initial tune to get the engine to a stable idle.

You can use a computer program to simulate engine operation to make sure that the engine tune that you have decided on works. You can use an engine simulator the plugs into the ECU of choice to do the same.

This allows you to stay in the concept phase without having to purchase EFI components, or fabricate parts/pieces necessary for the installation of the EFI system components. This does prolong the proposed EFI project, but if it is to be a learning experience for the possibility of doing an EFI project in the future, it can be time well spent. Need to remember that this will only get you to a starting point that may prove a project concept, not an engine tuning point.

TUNING

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Tuning a new ECU is where a very good understanding of the tuning parameters and how each is used by the ECU is paramount.

Tuning Software

The tuning software for the aftermarket ECU that I am using is Tuner Studio. This software is not specific to the Speeduino ECU that I am using, but the version I have is tailored for the Speeduino. It is recommended that you purchase the licence for this software, or the software you need, so that you can get the most out of your project.

The terminology used may not be specific to the Speeduino, but what the terminology means is applicable to all ECU tuning software applications.

In this section, I will provide my understanding of the software terminology and if possible, how each setting, table and such, interacts as a whole.

Most of the information that I will be discussing in this section is available to you in the Speeduino manual, information on the Speeduino forum, and information found on the internet. You are encouraged to read this information before starting a project.

The second tuning support software is MegLogViewerMS. This is an analytics software that allows you to review and analyze the data logs taken for a specific period. The full, licenced version is recommended.

Starting a Project

Before starting a project, recommend you determine your requirements and read the documentation provided with the tuning application. This will allow you to determine what you think are the best initial settings for your project. The recommendations that I will make regarding the tuning application settings are the ones that I started with.

Word of caution, my project is using the Speeduino ECU. This is not one of the Megasquirt family of ECUs, or other ECUs available and there are differences. You must divorce yourself from using Megasquirt recommendations as these generally do not work. This is similar to divorcing myself from the Honda CFI system and its design parameters. In essence, my project is a new EFI install, using the CFI components that were available to me.

The initial engine tune is done using essential initial tuning parameters that will enable me to establish a stable base idle from which to progress.

It is recommended to turn off tuning parameters not required at this stage, and once a stable base idle is achieved, start turning on these tuning parameters, one at a time, and progress with the engine tune. When doing this, always revisit what was done initially and adjust as required.

There are many tabs and associated settings to go through.

Settings Tab

Engine Characteristics/Constraints

Control Algorithm: This is the algorithm that uses either the MAP, TPS, or IMAP (Intake Manifold Absolute Pressure)/EMAP (Exhaust Manifold Absolute Pressure) sensor to determine the engine fueling calculation. Most tuning applications will use these sensors to determine engine load. Recommendation - MAP

Injector Staging: Alternating or Sequential, whether or not the injectors should be fired at the same time. Most EFI installs will use alternating injector staging if sequential injector staging is not being considered. Recommendation - Alternating

Sequential fuel injection differs from the alternating for this tuning software application in that sequential fuel injection will fire the injectors in the order required and try to spray fuel into the engine cylinder when that cylinder is about to fire - intake valve open and just before intake valve closes. This fuel injection method does not provide significant engine performance changes, or fuel economy improvements, and may only be beneficial at idle and low speed cruising. You must also have a second rotational input to the ECU for this parameter to be used.

Engine Stroke, Number of Cylinders, Number of Injectors: Self-explanatory settings

Injector Port Type: This is the number of primary injector ports. This setting is either Port or Throttle Body. Recommendation - Port

Engine Type: Most engines will be Even Fired, but there are exceptions. Recommendation – Even Fire

This section is specific to the Speeduino ECU. Other tuning applications may have a similar section.

Speeduino Board: Your chosen Speeduino or Speeduino clone board

Stoichiometric Ratio: generally, 14.7. Recommendation - 14.7

Injector Layout: How the injectors are connected for use – Paired, Semi-Sequential or Sequential. In my case with a wasted spark system, there are two injectors per injector circuit – Paired.

If you choose the Sequential setting in this section, the Injector Staging setting in the main body of this tab is ignored. Recommendation - Paired

MAP Sample Method: This is how the ECU determines the MAP sensor input signal to use in the fuelling calculations. For more than 2 cylinders, the ECU averages the MAP sensor input signal each engine cycle of 720 degrees. Recommendation – Cycle Average

MAP Sample Switch Point: This is the setting where the ECU will change how it determines the MAP sensor input setting to use for fueling calculations. Recommendation – 1800 RPM

Required Fuel (RF) Calculation: Based on the values in this tab and those you will put in the RF dialogue box. This is the theoretical amount of fuel injection time that would be required at 100% VE. Increasing the RF number

will influence the ECU fuel calculations such that there will be an increase in fuel injected at all points of the VE table, the converse as well.

Choose the units to be used, Imperial or Metric. I am using Metric.

Engine Displacement – 1200
Number of Cylinders – 4
Injector Flow 252
AFR – 14.7

The injector flow is the flow rate at test pressure, then reduced to the flow rate at the expected operating pressure, then prorated to the duty cycle percentage.

Injector Characteristics

Injector Duty Limit: industry standard for street use is generally no more than 85%. Specialized applications may allow less. Recommendation – 85%

Injector Open Time: This is the amount of time in milliseconds (ms) it takes for the fuel injector to open and start admitting fuel to the engine cylinder. This value includes the time the fuel injector takes to close after the ECU has ceased the fuel injector pulse width. This setting is also called "dead time", "injector latency". The fuel injector pulse width (PW) has three components that have been mentioned previously and is comprised of the injector opening time, fuel flow time and close time. Recommendation – start at 1.0 MS

Battery Voltage Correction Mode: Settings are "Open Time Only" and "Whole Pulse Width". Settings are in percentage and are input in the Battery Voltage Correction table. Recommendation – "Open Time Only"

Fuel Injector Close Angles: This is not being used.

Trigger Setup

Trigger Pattern: This is the "decoder" engine timing setting. There are many choices, but the most prevalent is "Missing Tooth" followed by "Dual Wheel". There are other choices but these are vehicle specific. If you use a dual wheel trigger system, there is no reason to remove a tooth on the primary trigger wheel. Recommendation – If you do not have a reason to use a Dual Wheel trigger system, use a Missing Tooth crank trigger wheel.

Primary Base Teeth: This setting is used for all Decoder settings. It is the number of teeth on the primary trigger wheel, crank or camshaft depending on your requirements, and includes the missing tooth of a Missing Tooth trigger wheel.

Primary Trigger Speed: crank or cam. I am using the Missing Tooth trigger wheel on the crankshaft.

Missing Teeth: depends on the application. For my install, setting is "1".

Trigger Angle (Deg): This number represents the angle ATDC when tooth #1 passes the primary sensor.

Skip Revolutions (Cycles): The number of revolutions that will be skipped during engine cranking before the fuel injectors and coils are fired. Remember, an engine cycle is 720 degrees, two rotations of the crankshaft.

Trigger Edge and Secondary Trigger Edge: Setting is "Rising" or "Falling". "RISING" is when the leading edge of the primary trigger wheel tooth, and possible the secondary trigger wheel tooth starts to cross the sensor pole piece. This setting is directly related to the coil driver setting of "GOING LOW" or "GOING HIGH". When the coil driver is set to "GOING LOW", this setting is generally set to "RISING".

Missing Tooth Secondary Type: Cam mode/type also known as Secondary Trigger pattern.

Trigger Filter: This setting determines the trigger filter algorithm. The more aggressive the filtering, the more noise is removed, but you could also filter out "true" readings and/or propagate "false" positive readings. The recommended setting when engine tuning is progressing is "Medium".

Inlet Air temperature (IAT) Density: This is the IAT correction table for air temperature - density. It is a table that defines the percentage increase in engine fuel enrichment or not, based on the ambient air temperature that the ECU will use to adjust the amount of fuel being admitted into the engine.

Barometric Correction: This is the barometric correction table for atmospheric pressure differences that the ECU will use to determine the engine fuelling requirements. Motorcycle EFI systems should have an ambient/atmospheric air pressure (AAP) sensor installed and devoted to this function.

If no real time AAP sensor is installed, the ECU will use the MAP sensor signal just before engine start as the AAP reference value for fueling calculations and store this single sensor value for the duration of the engine operation. This could be problematic especially if you intend to ride from an area at sea level to a more mountainous area.

If a real time barometric sensor is installed, the ECU will continuously monitor the barometric sensor signal input and adjust the fuel requirement to suit.
This is why an EFI system should have an AAP sensor signal in real time so that the calculated fuel requirement is as accurate as possible, mitigating the possibility of a fuel rich, or fuel lean engine condition.

Reset Control, Gauge Limits, I/O Summary, Programmable Outputs: These parameters will not be addressed in this document.

Tuning Tab

Acceleration Enrichment (AE): Sometimes called tip-in enrichment. AE is used when there is a sudden opening of the throttle for acceleration.

This tab is where the chosen engine load control is used to determine what the fuel enrichment will be for engine operation. This parameter will be further discussed separately when the bike is being tuned for the road.

AFR/O2 Sensor: These settings are used by the ECU to fine tune the AFR when the ECU is operating in the closed loop mode. Initial engine tuning generally has these sensor settings off, and in the "No Correction" setting. This enables you to do initial engine tuning using the VE, Spark and possibly AFR tables without having a different sensor changing the initial engine tune.

Engine Protection: The recommended setting for initial engine tuning is "OFF". These settings can be turned on after engine tuning or during more advanced tuning. The Engine Protection settings are:

Rev Limit
Boost Limit
Oil Pressure Protect
AFR Protect
Coolant Protect

Flex Fuel: Not applicable to this project.

Volumetric Efficiency (VE), Spark and AFR Tables: These are the primary tables, starting with the VE table, that will be used to determine the initial base idle.

Secondary Fuel and Spark Tables: These tables have some traction in the various forums. Depending on your requirement(s), you may want to venture into this world.

Sequential Fuel Trim: Not applicable to this project.

Staged Injection: Not applicable to this project at this time.

Spark Tab

Spark Settings

Ignition Load Setting: MAP and as discussed.

Spark Output Mode: The options for the Speeduino ECU are: Wasted Spark, Single Channel, Wasted COP (Coil-On-Plug), and Sequential Rotary. The most common is wasted spark. You will have to determine your requirement. Recommendation – Wasted Spark

Cranking Advance Angle (Deg): This is the timing advance angle that will be used for pre-engine start. This is a user defined setting. This setting allows you to set the ignition timing before an engine start.

Spark Output Triggers: This is the setting for the coil driver. Most coil drivers will use the GOING LOW, but there are some that require the GOING HIGH setting. If the setting is not known and you cannot find the information on the respective forums, you will have to determine the requirement through experimentation. The other option is to use the appropriate test tools available to determine the data needed.

Enable Fixed/Locked Timing: This timing setting will override the ignition - spark table until this setting is changed to "OFF". The cranking advance angle overrides this setting when the engine is cranking.

Fixed Angle (Deg): This is the timing advance angle that the ECU will use for engine operation and overrides the settings in the ignition/spark table. To revert back to the ignition/spark table settings, turn the "Enable Fixed/Locked Timing" to OFF.

New Ignition Mode: This is an updated tuning program. If timing issues are encountered, when using this mode, turn this setting OFF and revert back to the previous ignition mode. This is a setting that you will need to be monitored to make sure that it works as you expect it to.

Spark Table: This is the same Spark table as the one located in the Tuning tab.

Dwell Settings: These settings are for the coil dwell times. If you are fortunate to have the Cranking and Running dwell times for the coils you are using you will see results immediately. If not, you will need to find the coil dwell time sweet spot through experimentation, recommend 0.1 ms changes until you get the dwell time to the optimum setting. A Cranking Dwell of 4.5 ms and a Running Dwell of 3.0 ms is recommended as good starting settings for engine tuning if you do not have the specific data for the coils you are using.

Spark Duration: Spark duration, commonly called Burn Time, is measured in milliseconds (ms). This Spark Duration/Burn Time is the time from the peak firing voltage, when the ECU signal to coil driver is removed and the coil has reached a saturation point, and starts to discharge the coil charge through the spark plug to the point at which the coil charge can no longer sustain the spark. Recommended spark duration is between 1.0 and 2.0 ms.
Use Dwell Map: either ON/OFF. It is recommended to have this set to "OFF" for the initial engine tuning and normal engine operation. This means that the ECU will always apply the cranking and running dwell settings without any changes - corrections. You can set this setting to "ON" for future engine tuning. There is very little information available as to what the dwell map is, but I suspect the Dwell map is the Dwell Correction Table.

Overdwell Protection: This setting allows you to set the maximum coil dwell time to safeguard the coils. It is an ON/OFF setting. It is recommended that this setting be approximately 3 ms above the coil dwell settings, including the cranking dwell; example, cranking dwell at 4.5 ms, dwell protection setting at least 7.5 ms. My research indicates that most users will enable this setting.

Dwell Voltage Correction: This table is based on the electrical system voltage. The base voltage should be the alternator reference voltage setting of approximately 14.2 VDC. The dwell setting for this value will be "100" and

is a percentage value. I expect that this table is the Dwell map that is used, or not, and referred to in the "Use Dwell Map" setting.

IAT Timing Retard: This table is used to retard the engine timing by a specific number of degrees depending on the ambient air temperature. Retarding engine timing is used to reduce the possibility of engine knock when the air-fuel mixture is ignited too soon in the cylinder by the ignition system. Engine knock is an issue with non-EFI systems and should be closely monitored in the warmer climates and during the hotter seasons. Engine knock is noticed by the engine having a "pinging" noise.

Engine knock is different than pre-ignition in that pre-ignition is when the fuel ignites in the engine cylinder because of the engine cylinder temperature, and not because of an ignition event.

Cold Advance: A table that can be used to advance ignition timing when the engine is warming up. This table can also be used to retard engine timing to warm up exhaust catalytic converters in the cold. A third benefit is that it can be used as a safety feature to retard the timing when the engine operating temperature is hotter than normal preventing engine knock.

Start-Up/Idle Tab

Cranking Settings

Cranking RPM (Max RPM): This setting indicates to the ECU the RPM above which the engine is determined to be started. Settings in the 300 to 500 RPM range are not uncommon.

Flood Clear Level (%): This is the value as a percentage, that when the throttle – engine is not started, is kept above this percentage level the priming pulse and cranking fuel settings are disabled. This setting is used to prevent engine flooding, or to clear an already flooded engine.

Fuel Pump Prime Duration (seconds): Time that the ECU will initially start/stop the fuel pump to prime the fuel system. The fuel pump will stop after this time, but starts immediately when the engine is started. If the engine is started during this time, the fuel pump will not stop, but continue to operate.

Injector Priming Delay (seconds): This setting is the amount of time that the ECU will fire the injectors after the fuel pump prime and before the engine starts. This is designed to remove air from the fuel system through the fuel injector(s).

Cranking Enrichment Taper Time (seconds): The transition time from fuel cranking enrichment to ASE or engine run.

Cranking Enrichment Curve Table: This table is a coolant temperature-based table that uses the engine coolant temperature to determine if fuel enrichment is required just prior to engine start. The enrichment value is a percentage increase of the fuel injector pulse width.

Cranking Timing – Cranking Advance Angle (Deg): The ECU uses this setting to determine when an ignition event should occur when starting the engine.

Priming Pulse Width: This is a coolant temperature-based table that the ECU uses to determine if a fuel injector pulse width correction should be done according to the engine coolant temperature. The ECU will extrapolate a fuel injector pulse width based on the engine coolant temperature.

Warmup Enrichment (WUE) – Fuel Percent Multiplier: An operating fuel enrichment table that defines the fuel enrichment the ECU may apply to the fuel injector pulse width after engine start. The amount of fuel enrichment is based on engine coolant temperature.

The fuel enrichment "0" value is "100%" at normal engine operating temperature. A value greater than 100% is adding a certain percentage of fuel to the engine, a value less than 100% is decreasing the amount of fuel being added

The WUE enrichment curve is determined by engine use and the area that you normally ride in. The WUE curve will be different for a motorcycle in Florida, than one in Alaska.

After Start Enrichment (ASE) – Fuel Percent Multiplier: A start-up fuel enrichment table that defines the fuel enrichment the ECU may apply to the fuel injector pulse width after engine start. This fuel enrichment table is used as an interim fuel enrichment until the ECU "kicks" in the WUE table. This enrichment can be used to fill in the gaps on initial start when the AFR indicates a lean fuel condition, and the WUE has not taken hold of the enrichment fuel requirement.

The duration of ASE is generally 1-2 seconds for an engine at operating temperature, and up to 20 seconds for a cold engine. The enrichment percentage is based on engine coolant temperature.

Idle Advance Settings: These settings and tables, depending on the idle advance mode of OFF, Added, or Swithced, determines how the ECU determines the correct ignition timing.
The OFF setting allows the ECU to use the Spark table for ignition timing, when it is not overridden by any of the locked timing features.

The ADDED setting allows the ECU to use the Spark table for ignition timing, supplemented by the idle advance curve table.

The SWITCHED setting overrides the spark table values, and the ECU uses the Idle Advance Setting tables.

Initial setting for the Idle Advance Settings is "OFF".

Accessories Tab

Thermo Fan: This setting allows the ECU to control the operation of the radiator fan. This can be advantageous if you do considerable amounts of start/stop riding, or ride in hotter climates. This feature is not being used in this project.

Launch Control/Flat Shift: This feature is not being used in this project.

Fuel Pump: The ECU controls the operation of the fuel pump through the fuel pump relay. This is a grounding circuit.

Nitrous: This feature will not be used in this project.

VSS and Gear Detection: This feature will not be used in this project.

Boost Control: This feature will not be used in this project.

VVT (Variable Valve Timing) Control: This feature will not be used in this project.

WMI (Water-Meth Injection) Control: This feature will not be used in this project.

Tacho: This feature will use the ECU system default settings.

CANBUS Secondary Serial IO Interface: This set of features are disabled.

Fuel-Oil Pressure Transducers: These sensors will not be used for this project. There may be a follow-on project regarding these sensors.

Tools Tab

This tab houses the various sensor calibrations that must be done to ensure the ECU has the correct sensor signals for optimal operation of the engine.

The sensors needing to be calibrated are:

WBO2 sensor
Coolant temperature sensor
Air inlet temperature sensor
Throttle Position Sensor

Important Consideration(s)

The fuel injectors are a key component in the operation of the EFI system because this is a fuel injection - delivery system. The fuel injectors are controlled by the ECU, and deliver the required fuel amount based on the sensor inputs to the ECU.

Accurate data is required for the fuel injectors. The fuel injector pulse width at idle is the tuning goal. This is based on normal engine operating temperature, ambient air temperature, and barometric pressure for the area that you ride in. There are other parameters that provide the ECU with fuel injector pulse width adjustment.

Fuel injector "dead" time (injector latency). This, as previously mentioned, is the amount of time needed to open the fuel injector such that it flows fuel into the engine cylinder. This "dead" time also includes the time to close the fuel injector at the end of the fuel injector pulse width. There is no fuel flowing into the engine cylinder during this time. This setting, if not as accurate as possible, has a domino effect throughout the engine operating range, and depending on the operating range, can affect engine performance.

Coil Dwell Time. An accurate dwell time prevents damage to the coil(s), and provides the appropriate coil charge to the engine cylinder through the spark plug for complete combustion. The coil(s) will charge to the appropriate level to ensure that the coil charge is sufficiently powerful to provide the engine cylinder with the required coil discharge.

Coils have a lag in the current flow when the dwell time starts. It takes a bit of time to have maximum current flowing through the coil(s). This is because coil charge time is a factor of turns ratio, primary resistance and input voltage.

Industry standard for coil charge time is a maximum of 4 ms, but is generally in the 1.5 ms range for modern coils. This provides us with a guide in how long the dwell time is for the coils of choice. Older coils such as those used by the GL1200 may need a charge time of greater than 1.5 ms.

Spark Duration affects engine performance and is directly related to engine timing. The layman thinks of timing as when the engine cylinder fires, and this is exactly correct. We set the timing to ensure the engine operates correctly, gives us the most power and best fuel economy. Never really think about Spark Duration, or if it even exists.

Coil dwell time affects this parameter. The coil dwell time has to end just as the ECU decides to fire an engine cylinder. The coil charge will start to dissipate through the spark plug at this time for the respective Spark Duration. The Spark Duration has to be sufficiently long enough to dissipate the coil charge completely. The ECU must also ensure that the coil has sufficient time to discharge the coil charge completely before the ECU has the coil revert back to a coil charge dwell cycle.

The accepted spark duration is between 1.0 and 2.0 ms.

Tuning

Tuning

The black art of having the EFI system do exactly what you want, when you want. The fortunate part is that this is not a black art, it is a learned art. The experts in this field came up through the ranks and we can do the same. I have mentioned previously that the key to tuning an EFI system is to read, then read again, and once this is done, read again. View every on-line video relating to tuning an EFI system, especially those that are related to the EFI system and ECU you are going to use.

An ECU replacement-upgrade project requires exactly the same process as if this were a new EFI install-conversion.

There is no definitive guide available for you to buy, or find on the internet that details the step-by-step process to tuning an EFI system. There are on-line courses that you can apprise yourself of, but most of us heading down this road will ultimately want to do the work ourselves. It also depends on your budget and what you want to achieve.

What is needed is a certain resolve that will entail a lot of homework researching EFI tuning, learning the acronyms, building a library of information that will assist you as you progress. You will read a lot of information, some relevant, some not. You will notice in a forum thread completely unrelated to your project a snippet of information that is related to your project. Take note of the information and make sure you catalogue it for future reference.

There is a lot of guidance from people who have been tuning for many years. These people came through the school of hard knocks as well, had to learn about an EFI system, the vernacular used, and through trial and error, became proficient at tuning an EFI system.

You have to be selective in what you accept as how to proceed and the way forward. The initial tuning advice is consistent, but the follow-on advice is not quite so. When to tune a specific parameter, what to expect from this when done, and how this tuning affects the other aspects of the engine tune is not easy to find. Case in point, spark duration.

Industry standard is between 1.0 and 2.0 ms. Below 1.0 ms there may not be enough time to deliver the coil charge during an ignition event. A spark duration of more than 2.0 ms may be too long a duration and an ignition event will run out of coil charge, affecting engine performance. This is dependent on the EFI system design.

This section will have a lot of information duplication, but it will be beneficial.

This is the point where you have to be patient working on your EFI system and project, and especially with yourself.

Starting

What do we novices know about tuning, only what we have read and what has been recommended. The sequence of tuning events is an elusive commodity. Since we are novices at this tuning concept, it is probable that we will want to get to the end result faster than possible, and in doing so, be all over the map with regards to adjusting the various settings. This should be avoided because you will, as I have done, change too many variables and not know what did what to whom. This is a difficult habit to break, but it must be done. Having a log of the initial settings, especially what the initial cell values were in the various table, allows you to regroup and start again.

Understanding the relationships between the various parameters can provide a basis for the sequence of events.

It is necessary to remember that when you are starting to tune the engine, tune one parameter and get it right, then move onto the next. If you jump around between tune parameters, you never know what parameter has done what. This will also entail patience in that a change in a parameter setting may take time to be fully realized. Once you have a tuning parameter set, revisit the previous tuning parameters and determine if a tweak of the parameter is warranted.

The first issue is to start the engine with the base tune that has been developed from the recommended base tune, and input from the tuning software.

The requirement here is to start the engine and increase-decrease the idle such that the engine stays running.

The next tuning issue is to adjust the VE table such that the engine has a stable idle, and you reduce the idle to what you expect the base idle to be, somewhere around the 900 RPM range.

You will be monitoring the MAP sensor reading and the requirement is to have the lowest MAP reading possible. This will be engine dependent, and may or may not be as recommended.

Once you get a stable idle and consistent engine start, next step is to adjust the Spark table cell values to enhance the stable engine idle that you have achieved. This will require you to revisit the VE table and adjust it as required. An iterative process between the two tables.

These two tuning aspects are about the only tuning procedures that I have found that are agreed upon by the experts in the tuning world for the ECU I am using.

Having mentioned the above, I have formulated a follow-on tuning process that should allow me to bring the engine tune to fruition.

It is mentioned in the various forum threads that coils and fuel injector data is a close second to adjusting the VE and Spark tables.

Fuel injector data, specifically fuel injector "dead time"-"latency" needs to be as exact as possible. This affects the fuel injector pulse width necessary to ensure that the correct amount of fuel is delivered to the engine. This fuel injector data can be from the manufacturer of the fuel injector, or from an iterative process using the engine as the test bed.

Use of fuel injectors that are not new – visit to an automotive scrap yard, have or have not been through a servicing process is generally based on what a person has gleaned from the various forum threads. The data that a person has used may or may not be what is needed, and an experimental process will still need to be done.

The electrical system voltage needs to be considered. The standard electrical system voltage for normal operation should be approximately 14.2 VDC – regulator-rectifier (RR) reference voltage. The ECU may use a correction value from the Injector Voltage Correction table depending on the electrical system voltage.

Maintain the electrical system in as good a state as possible is a key element in the operation of the EFI system. You want to do the initial engine tune adjustments with the electrical system voltage as close as possible to that of normal operating voltage.

The next tuning parameter that I would recommend is to dial in the ignition coil dwell time. I have mentioned previously what procedures can be used to determine the best ignition coil performance. One of these procedures should provide you with a way ahead to have the ignition coils dialed in for your EFI system.

The Spark Duration needs to be adjusted at the same time as the ignition coil adjustment. This setting adjustment should be in the 1.0 and 2.0 ms range. It has been mentioned previously how this timing affects the engine performance.

At this stage in the engine tuning process, you have the fuel and ignition requirements sorted out to the best of your ability, and the engine is working as you expect it to.

The next steps are a guesstimate of where to proceed from here.

Enable the O2 sensor. The O2 sensor determines the exhaust oxygen content and provides a signal to the ECU such that the ECU adjusts the fuel amount to maintain the required AFR. This is an after the fact correction.

Enable Idle Advance Settings. No too sure what this about.

Tuning Notes

These pearls of wisdom have been gleaned for various forum threads. The order in which each is done is a personal choice.

Coil Dwell – at idle, in Dwell Settings, reduce the Running Dwell until the engine starts to misfire. Increase the dwell until the engine no longer misfires, then add 0.02 ms to the dwell time. This should give you the "minimum" dwell time at idle.

The Finer Details

There are quite a few ECU tuning software parameters that are not at the forefront when you start engine tuning. These are follow-on parameters that you eventually get to.

These parameters are the fine-tuning parameters of the engine tune. Most of these require you to research the issue so that you can understand what it is being discussed, and how to proceed with each one, sometimes just to learn what the acronym means. Information should be available in the ECU manuals, but this is dependent on the ECU of choice. My ECU of choice is an open-source ECU product, and most of the literature regarding the ECU engine tuning parameters is by voluntary contribution.

The Megasquirt family of ECUs is quite mature as is the manual. There are other aftermarket ECU manufacturers that are like the Megasquirt family of ECUs, but the product software, operation and such is generally intellectual property.

My reading and research indicate that the information regarding these fine-tuning parameters is not easily found, but out there for you to find.

Acceleration Enrichment (AE) – Tip-In Enrichment

This is the EFI equivalent to the accelerator pump in a carburetor. The tip-in AE is basically the ECU enriching the air-fuel mixture (adding extra fuel to the mix) to compensate for the increase in air flow that is coming because the accelerator has been suddenly depressed, and the ECU has not caught up to the engine requirements.

Acceleration Enrichment is required to momentarily enrich the air-fuel mixture when the accelerator is suddenly depressed at idle and low speeds. If this were not the case, you would find that the engine would be operating in a fuel lean state, not good for the engine, until the ECU catches up with the engine RPM and the fuel flow to the engine is based on the VE table.

You can adjust the AE tip-in using TPS, or MAP engine load setting.
The first stage in engine is to do so at idle, and adjust the VE table values to get a stable idle. This is followed by adjusting the Spark table values.

The MAPdot, or TPSdot can be represented as a percentage-based fuel increase, or a time-based fuel increase in ms. Either can be used, but using a percentage-based fuel increase makes it easier when/if you decide to swap out injectors.

There are many YouTube videos that discuss AE.

You want to tune the engine at idle such that when you quickly "blip" the throttle, the ECU enriches the air/fuel mixture to compensate for the potential lean fuel condition that exists because of the sudden change in air flow.

Depending on the duration of the sudden change in engine operation, there is a Taper Start-End setting. These settings allow the ECU to gradually reduce the amount of enrichment over a specific RPM range depending on the delta over time of the TPS or MAP sensor.

Taper Start – This value is engine RPM. It is the RPM where AE starts to reduce
Taper End – This value is engine RPM. It is the RPM where AE should not be needed and the ECU is using the VE table to determine the air-fuel mixture.

You can use the TPS and MAP in conjunction with each other. You can use the TPS for AE because it is the first sensor to indicate to the ECU that the throttle has been opened, much sooner than the MAP sensor. This allows the ECU to enrich the air-fuel mixture sooner than if the MAP sensor was being used for AE, and reduce the AE sooner when the throttle position is where it should be. The SD fueling based on the MAP sensor can be used for the main fuel calculations.

Tuning Strategies

Initial Engine Tuning – Turn off-disable all non-essential parameters that can impact on the initial engine tuning. Detailed list to follow.

Spark Table – having a column in the spark table that is at a lower than idle speed, VE table to match, for an engine speed that is less than normal idle speed. Each cell in this column has several degrees of ignition advance that is greater than the cells in the column for normal idle speed. This column should ensure that should the engine idle drop below normal idle speed, the increase in ignition timing will speed the motor up to normal idle speed preventing the engine from stalling.

Coils – Once the initial engine tune is determined, it is time to look into fine tuning. Coil dwell can be tuned for idle and for operation. This is through experimentation. At idle reduce the dwell time until the engine starts to stumble/misfire, then increase the dwell until the engine smooths out and operates well. Use this as the base for street tuning. Determine a street procedure and make several street runs to adjust the coils dwell to suit. When tuning the coils for idle/street operation(s), adjust the coil dwell in small increments until you have the coil dwell adjusted for idle and street use.

Autotune – Tune Analyze Live: This feature has Tuner Studio monitor the engine operation and adjust the VE table values to get the AFR settings closer to target values. This feature is generally used once you have a good base engine tune.

VE Table – The VE table is the first parameter to adjust to get an initial engine idle.

The displacement of the engine is constant; the VE is a variable. VE is the variable used to tune the engine. VE is a measure of how well the cylinder is being filled compared to the potential volume.

You adjust the VE value to achieve the desired AFR for the load and speed being tuned for. Once you have found this VE value that achieves the desired AFR for the engine at that particular load and speed, you have found the accurate VE value for the engine at that specific load and speed.

The VE of the engine for that load and speed will not change unless you change mechanical parts. This truism states that the engine will flow the same volume of air regardless of the engine location, sea-level or in the mountains. What happens is the ECU determines the engine operating parameters, and calculates the required fuel for the given set of conditions.

With engine at operating temperature, engine at required idle speed, reduce fuel by adjusting the VE cell values. If the engine RPM slows, MAP rises, or engine starts to stumble – adjust the VE cell values the other way until the engine smooths out. Adjust fuel by increasing the VE cell values until the engine falters. Reverse fuel settings until engine smooths out. Take note of the AFR-Lambda reading. If there is a difference in the VE cell values where the engine has smoothed out, average the VE cell values to pick an optimum value.

Once the VE table is properly calibrated, you will have an accurate air flow table for the engine, and no further adjustments will be required.

Calculating air density has apparently been removed from the Speeduino programming and been replace with a base calculation for air density done by the Tuner Studio software when it does the Required Fuel (req fuel – RF) calculation. In the firmware this is corrected up/down based on the IAT Density Correction Table.

Second set of parameters for initial tuning: Priming, ASE and WUE tables. Minimum tuning, should be nearly zero

Understanding Cold Engine Starting

Cold engine starting is one of the most difficult aspects of starting an engine be it a carbureted fuel or an EFI system. The amount of fuel needed for a successful start and run an engine up to normal operating temperature is difficult at best. The ECU has to contend with fuel that is not vapourizing as the fuel would at engine normal operating temperature. To assist the ECU in determining the correct air-fuel mixture, there are 3 fuel enrichment percentage curves that the ECU uses to determine the fuel load on start and initial warm up.

These curve tables are the Cranking Enrichment Curve, After Start Enrichment (ASE) and Duration Curves, and Warm Up Enrichment (WUE) Curve. Each curve represents a fuel enrichment percentage before and after engine start.

The ASE Duration curve represents the amount of time the ASE fuel enrichment curve will be used, typically between 1-2 seconds when the engine is at normal operating temperature, and up to 20 seconds when the engine is started from cold. This ASE duration curve is based on engine coolant temperature.

The ECU uses the Cranking Enrichment Curve during cranking based on the engine load-RPM value in the VE table. The ASE and WUE fuel enrichment curve tables are used the same way.

Once the WUE fuel enrichment curve table is being used by the ECU to determine the correct air-fuel mixture, the cranking and ASE fuel enrichment curve tables are no longer used.

The ECU adjusts the fuel injector pulse width to accommodate the engine coolant temperature according to the fuel enrichment percentage curves. If the fuel injector pulse width is approximately 3.4 ms (this includes fuel injector dead time-injector latency) for the load-RPM, and the fuel enrichment percentage is 20% according to the table curve being used, the fuel injector pulse width will be increased by 20% to a pulse width of 4.08 ms. As the engine coolant temperature changes, the fuel injector pulse width will be adjusted to suit the indicated fuel enrichment percentage until there is no more requirement for fuel enrichment.

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