# "Gentlemen, Start Your Engines"

## Here's what the ECM does when you start the car.

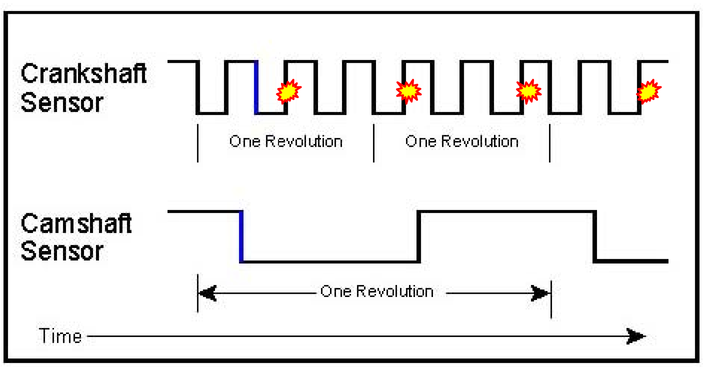
**GN and Turbo Regal** **Dennis Leek** (dmdl@snip.net) 7-29-2003

*The information contained in this article is based on the 1986/87 Buick turbo V6 ECM. EPROM addresses are shown as well as the formulas to calculate data values for those who are interested and/or capable of PROM burning.*

The following article describes how the fuel delivery and spark advance during engine cranking is controlled by the Engine Control Module (ECM) or as it is commonly known, the "computer".

**Cranking Mode:** As the engine begins cranking, the ECM energizes the fuel pump relay for 0.7 seconds. (This is under ECM hardware control, not software.) The fuel pump then pressurizes the fuel rail. While this is happening, the ECM clears the memory (except for the Block Learn Memory and the portion used to store error codes), initializes control values like Injector Offset vs. Battery Volts and others, sets the Integrator and BLM values to 128, and reads the current coolant temperature and throttle position.

The ECM primarily uses the crank signal to determine the proper air/fuel ratio for starting the engine. This ranges from approximately 1.5:1 at -33 °F to 14.7:1 at 201 °F. The desired air/fuel ratio is achieved by turning on or pulsing the fuel injectors for an amount of time calculated to produce the desired air/fuel ratio. Before the injectors will fire, the ECM (hardware) has to see the Camshaft Sensor signal go low then the Crankshaft Sensor signal go low. This can occur within less than one-half Crankshaft revolution or it may take as many as two crank revs. It depends on where the camshaft was when the engine was turned off. After the ECM sees the cam and crank pulses, it uses the crankshaft signal to fire the injectors. During cranking, all the injectors are pulsed at the same time (simultaneously) unlike the normal operation of pulsing one-at-a-time (sequential). Every 3rd reference pulse from the Crankshaft Sensor causes the injectors to fire.




The spark advance while starting is fixed at 10 degrees BTDC. This is controlled by the ignition module and not the ECM. The ECM uses both hardware and its stored program to monitor the RPM.

When the engine reaches 400 RPM, the ECM hardware sends a Bypass signal to the ignition module that makes it switch to ECM control. [$E3A7] Under program control, the ECM leaves the starting mode and switches to the run mode 10 ECM cycles ($163) after the RPM reaches 400 ($161). Initially, the fuel requirements for run mode are managed by the open loop fuel controls, then later by the closed loop fuel controls. While in open loop, the ECM uses fixed numbers to set the amount of fuel. In closed loop, it uses the Oxygen Sensor output voltage as the primary fuel regulator.

**Cranking Fuel:** The first thing the ECM does [$3977] in preparation for the fuel calculation is read a table ($555) that has throttle position (TPS) ($36) as the index. The output from this table is used as a multiplier in the injector pulse-width (on time) calculation.

Although you don't normally push down the gas pedal during cranking, if it *is* depressed 38 – 50%, then 8 percent more fuel is injected. At 63% throttle, 17% more fuel is added. At the 75% and 88% entries in the table, the multiplier is *zero*. This is done to facilitate clearing a 'flooded' engine of excess fuel.

| Cranking Fuel Multplier vs. TPS ($555) | | | |
|---|---|---|---|
| TPS% | Data Value (hex / decimal) | | Multiplier |
| 0 | 80 | 128 | 1.00 |
| 13 | 80 | 128 | 1.00 |
| 25 | 80 | 128 | 1.00 |
| 38 | 8A | 138 | 1.08 |
| 50 | 8A | 138 | 1.08 |
| 63 | 96 | 150 | 1.17 |
| 75 | 00 | 0 | 0.00 |
| 88 | 00 | 0 | 0.00 |
| 100 | 80 | 128 | 1.00 |

Sets Clear Flood mode (TPS 75 and 88)

**Cranking Max PW Multplier vs. TPS% (0 – 200%)**
- table value stored temporarily in $45
Throttle position determines how much of the calculated injector pulse-width is to be used during cranking.

Formula: `TPSMult=N/128`

**Clear Flood Mode:** If the engine floods, it can be cleared by pushing the accelerator pedal almost all the way down (75% to 88%), holding it there for a few seconds then releasing. When the ECM sees that the Crank Fuel Multiplier vs. TPS = 0, it goes into the clear flood mode. A multiplier of zero produces a calculated injector pulse-width of zero. A small amount is added because of the Battery Voltage Offset table (as is always), but not enough to start the engine.

There is some ROM code left over from an earlier version that during clear flood mode, wants to produce an air/fuel ratio of 20:1. This code forces the Reference Pulse counter to zero [$E229] and the coolant temperature to a value representing 111 ºF ($28A) [$F377]. These two parameters affect the output of two tables used in the fuel calculation. These tables are described below however, the program for the 86/87 turbo V6 makes the TPS multiplier ($555) zero which in turn, makes the fuel calculation equal zero.

When the ECM sees the throttle position become less than 75%, it returns to the normal starting mode. If the engine "fires" while the gas pedal is held down, the ECM will leave the clear flood mode when the RPM reaches 400.

**Cranking Fuel (continued):** [$3983] The ECM temporarily stores the multiplier from the TPS table ($45), then it reads another table ($536) to determine the maximum pulse-width for a given temperature range.

| Cranking Max Injector PW ($536) | | | |
|---|---|---|---|
| Coolant Temp (°F) | Data Value (hex / decimal) | | Injector PW |
| -40° | FF | 255 | 99.6 msec |
| -18° | FF | 255 | 99.6 msec |
| 3° | C8 | 200 | 78.1 msec |
| 25° | 90 | 144 | 56.2 msec |
| 46° | 54 | 84 | 32.8 msec |
| 68° | 30 | 48 | 18.8 msec |
| 90° | 2A | 42 | 16.4 msec |
| 111° | 24 | 36 | 14.1 msec |
| 133° | 1A | 26 | 10.2 msec |
| 154° | 14 | 20 | 7.8 msec |
| 176° | 10 | 16 | 6.3 msec |
| 198° | 10 | 16 | 6.3 msec |
| 219° | 0E | 14 | 5.5 msec |
| 241° | 0E | 14 | 5.5 msec |

**Cranking Maximum PW vs. Coolant (0 – 99.6 msec)**

- table value not stored

The maximum injector pulse-width to use during cranking as determined by coolant temperature ($1E)

Scaled by Max Inj PW Scaled ($534)

Formula: `MaxPW = N/256 x MaxPW_Scaler`

**Example:** The engine is cranking while the coolant temperature = 68 °F.

```
MaxPW = 48/256 x 100
MaxPW = 0.188 x 100
MaxPW = 18.8 msec
```

The Cranking Max Inj PW (table $536) is scaled by a fixed multiplier ($534) to produce the maximum injector pulse-width for a given temperature. The scaler ($534) actually establishes the max pw size and the Max PW table ($536) is really a percentage of max. The two are labeled here the way Buick intended. It doesn't matter what they're called because they are both multipliers used to produce a Max Injector PW. This number is stored ($83) but will be modified based on other conditions.

| loc | control | hex | decimal | value |
|---|---|---|---|---|
| $534 | Cranking Max Inj PW Scaler | 199A | 6554 | 100 |

Formula:
`MaxPW_Scaler = N/65.536`

To achieve proper combustion in what is probably a cold engine, the ECM needs to vary the injector pulse-width during the first few revolutions. It needs to start with a fairly healthy squirt, then deliver not quite as much as the engine turns faster. To accomplish this, it uses a Reference Pulse count ($E2) that is triggered by the Crank Sensor. The Crank Sensor provides six pulses for each revolution of the camshaft.

| Cranking Fuel Multplier vs. Ref Cnt ($544 | | | |
|---|---|---|---|
| Refence Pulse Count | Data Value (hex / decimal) | | Multiplier |
| 00 | 80 | 128 | 0.50 |
| 08 | C0 | 192 | 0.75 |
| 16 | A6 | 166 | 0.65 |
| 24 | 8C | 140 | 0.55 |
| 32 | 72 | 114 | 0.45 |
| 40 | 58 | 88 | 0.34 |
| 48 | 40 | 64 | 0.25 |
| 56 | 40 | 64 | 0.25 |
| 64 | 40 | 64 | 0.25 |
| 72 | 40 | 64 | 0.25 |
| 80 | 40 | 64 | 0.25 |
| 88 | 72 | 114 | 0.45 |
| 96 | 72 | 114 | 0.45 |
| 104 | 72 | 114 | 0.45 |
| 112 | 72 | 114 | 0.45 |
| 120 | 72 | 114 | 0.45 |
| 128 - 256 | 72 | 114 | 0.45 |

**Cranking Fuel Multplier vs. Reference Count (0 – 100%)**

- table value not stored

Cranking injector pulse-width reduction percentage determined by Reference Pulse count. Reference pulses originate from the Crankshaft sensor.

Table value formula: `RefMult = N/256`

**Example:** The Max Injector PW was previously calculated to be 18.8 msec. If the Reference Pulse Count was 80 (arbitrary), the injector pulse-width would be reduced by 0.25 (25%) to 4.7 msec.

```
InjPW = MaxPW x RefMult
InjPW = 18.8 x 0.25
InjPW = 4.7 msec
```

After the injector pw is reduced by the output of the Reference Count table, it is stored ($83).

The "rule of thumb" says as temperature goes down, the fuel amount should go up. Apparently, the engineers felt that cranking a cold engine required a *leaner* mixture. They added a table ($5E8) that, when the temperature is below 47 °F ($466), produces a multiplier that will reduce the injector pulse-width as the engine rpm increases. I'm guessing maybe this was an "emissions" thing.

| Cranking Enleanment Scaler ($5E8) | | | |
|---|---|---|---|
| Engine RPM | Data Value (hex / decimal) | | Multiplier |
| **000** | FF | 255 | 1.00 |
| **050** | FF | 255 | 1.00 |
| **100** | FF | 255 | 1.00 |
| **150** | FF | 255 | 1.00 |
| **200** | F3 | 243 | 0.95 |
| **250** | E6 | 230 | 0.90 |
| **300** | DA | 218 | 0.85 |
| **350** | CD | 205 | 0.80 |
| **400** | C0 | 192 | 0.75 |
| **450** | B3 | 179 | 0.70 |
| **500** | A6 | 166 | 0.65 |
| **550** | 9A | 154 | 0.60 |
| **600** | 80 | 128 | 0.50 |
| **650** | 80 | 128 | 0.50 |
| **700** | 80 | 128 | 0.50 |
| **750** | 80 | 128 | 0.50 |
| **800 on up** | 80 | 128 | 0.50 |

**Cranking Enleanment Scaler (0 – 100%)**
- table value not stored

Used during cranking to reduce the injector pulse-width when the coolant temperature is below 47 °F ($466).

Index = Engine RPM

Table value formula: `CEMult = N/256`

**At 400 RPM, the engine is considered "started", so the bottom of the table is not used.**

Above 47 °F, the Cranking Enleanment Scaler table is not used.

## Cranking Fuel Calculation:

`CrankPW = TPSMult x (MaxPW x Scaler) x RefMult x CEMult` (if below 47 °F)

**Example (continued):**
```
CrankPW = 1.00 x (0.118 x 100) x .25
CrankPW = (11.8) x 0.25
CrankPW = 2.95 msec
```

[$3F7F] After the ECM calculates the cranking injector pw, it checks that the pw is greater than 0.49 msec, then it adds a small amount based on the output of the Battery Offset table ($4C1). (This table is described in the article on Basic Fuel.)

[$3FA1] During cranking, each injector is pulsed *twice* during each revolution and all the injectors are "fired" at the same time. The injector control hardware in the ECM makes this happen but the hardware is under ROM program control [$FDAF].

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