

"Knock, Knock." Who's there?

This is no joke. Detonation is your engine's worst enemy.

GN and Turbo Regal

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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.

Introduction: The engine's knock sensor detects engine sounds resulting from detonation and signals the ECM. The ECM responds by retarding the ignition timing in an attempt to make the knocking stop. It is the purpose of this article to describe how this portion of the electronic engine management system works but not the many causes for engine knocking. The portion of the ECM used for "knock management" is called Electronic Spark Control (ESC).

The Knock Sensor and ESC Module: The detonation or knock sensor as it is called, is a piezoelectric sensor located at the back of the engine, on top near the intake manifold. (You can see it if you look from the driver's side.) A piezoelectric device is one that converts vibration into electrical signals. The knock sensor generates electrical impulses directly proportional to the frequency of the knock detected. The sensor in the turbo 3.8L has a resonant frequency of 6 KHz.

The knock sensor is connected to the ESC module (mounted to the p/s inner fender). The ESC module's job is to discriminate between normal engine noise and knock. It contains specialized filters that pick out the signals related to knock then produce a signal with a duration proportional to the knock intensity. Each knock has to occur for a minimum of 5 msec before the ECM is notified. The ESC module has a single output to the ECM, which is normally at 8 – 10 VDC (called a "high"). When knocking vibrations are detected, this line goes "low" (0 V) and stays low for a period of time determined by the knock intensity.

ECM Knock Processing: The ECM converts the ESC signal into a number that is determined by the length of time the ESC signal is held low (the duration of the knock). The way it works is, a counter is allowed to count up only while the ESC input is low. This counter is called the ESC PA (pulse accumulator). The longer the knocking occurs, the higher the count gets. The higher the count, then the greater the retard to the timing. When knocking stops the counter stops, but the count remains at the last number. This is the starting number for the next knock event. The ESC PA can count from 0 to 65,535, although it will never count that high. The amount of detonation it would take for the maximum count would cause *extreme* engine damage.

The rate at which knock retard is applied is called the *attack rate*. The rate at which this retard is removed is called the *recovery rate*. The attack rate is much faster than the recovery rate. The retard amount (attack rate) can possibly increment every 12.5 msec, whereas the recovery rate is calculated only once every 200 msec. From this, you can see the amount retard can accumulate (at almost a 20:1 ratio) before any attempt at recovery.

[**\$E5FC**] During every other pass through the ROM code, the ESC PA (**\$0C0A**) count is read and compared to the previous count. The new count is stored (**\$5E** and **\$5F**) and the difference between the new and previous count is determined. This count difference represents the new knock event.

The ECM reads the ESC PA count every 12.5 msec. Because of the counter's clock rate, the most the count can increase for a single knock event is 208.

Before the change in ESC PA count is used to retard the timing, several checks are made:

- Has the engine has been running for less than 1 second (\$174)? If so, make the retard = 0.
- Is the engine coolant temp below 46 °F (\$179)? If so, make the retard (\$62) = 0.
- Is the engine RPM less than 1000 (\$176)? If so, skip the ESC processing and continue calculating the spark advance.
- Is the battery (really alternator, I suppose) voltage below 9.3V? If so, make the retard = 0. *This is a test for cranking and the voltage level is hard coded.*
- Lastly, has a malfunction been detected in the ESC circuit? If so, make the retard = 10 degrees (\$2B6).

If none of the previous conditions is met, the ECM determines how much retard to apply based the “severity” of the knock. This is indicated by the ESC PA count. Severity is based on knock duration and nothing else. The Attack Rate table (\$23C) tells the ECM the number of degrees of retard to apply for each millisecond of knock.

ESC Attack Rate (\$23C)			
Engine RPM	Data Value (hex / decimal)		Retard (degrees)
400	08	08	0.18
1200	08	08	0.18
2000	09	09	0.20
3200	0E	14	0.31
4800	0E	14	0.31

ESC Attack Rate (0 – 5.7 degrees)

- table value not stored

Table provides number of degrees of retard for each millisecond of knock

Index is engine RPM.

Table value formula: $ESC_Attack = N \times 0.0225$

The value from the Attack Rate table is multiplied with the ESC PA delta (difference). The product of the multiplication is doubled, then added to the current amount of ESC Retard Degrees (\$62).

For example, the knock sensor detects detonation, and suppose the knock lasts long enough for the ESC PA count to increment 110_{10} . The knocking just occurred, so the difference between this reading and the previous reading is 110_{10} . The ECM goes to the Attack Rate table and let’s say the RPM is 4000, so it reads 14_{10} . The 14 is multiplied with the 110, and then the result is doubled.

Here’s the math for this example:

$$\begin{aligned}
 ESC_Retard &= (ESC_Delta \times ESC_Attack_Rate \times 2) / 256 \\
 ESC_Retard &= (110 \times 14 \times 2) / 256 \\
 ESC_Retard &= (3080) / 256 \\
 ESC_Retard &= 12.03 - \text{rounded down to } 12
 \end{aligned}$$

The result (12) is stored as the ESC Retard Degrees (\$62). To see how many degrees this actually is, perform the following:

$$\begin{aligned}
 Degrees &= (N / 256) \times 45 \\
 Degrees &= (12 / 256) \times 45 \\
 Degrees &= (0.039) \times 45 \\
 Degrees &= 2.1
 \end{aligned}$$

The ECM divides the retard in half before applying it to the previously calculated spark advance (\$58). This is because it will be applied twice before the ECM checks the ESC again.

In the example, a total of 2 degrees (1 degree applied twice) is subtracted from the spark advance. Suppose that on the next time through this code, the knock count is 260_{10} (it got worse). The previous count is subtracted from the new count, making the difference 150_{10} . The new ESC Retard will be 16 and the new retard amount will be 2.8 degrees. This gets added to the previous retard of 2.1 for a total of 4.9 degrees removed from the spark advance because of knock detection.

Because the knock retard is accumulative, there has to be a limit to the amount the ECM will apply. Before the ESC Retard Degrees (\$62) is saved, it is checked for one of two limits. During normal driving, *I should rephrase that*, if the ECM is *not* in Power Enrichment (PE), the limit is 15 degrees (\$177). If PE is enabled, the retard limit is 29.9 degrees (\$178). If the calculated amount of retard exceeds the limit, it is simply set to the limit.

The remainder of the timing code is explained in detail in the article on Spark Advance.

The Knock Retard Degrees (\$62) is checked in the boost code [\$3849] for >15 degrees (\$775). The Wastegate duty cycle is reduced if it is. It is also used by the knock recovery code.

Knock Recovery: Every 200 msec., the ECM uses engine RPM to index the ESC Recovery Rate table (\$241). The current ESC Retard Degrees (\$62) is then reduced by the percentage amount from this table.

ESC Recovery Rate (\$241)			
Engine RPM	Data Value (hex / decimal)		Recovery (%)
400	FF	255	498
1200	18	24	47
2000	10	16	31
3200	10	16	31
4800	14	20	39

ESC Recovery Rate (0 – 498%)

- table value not stored

Table provides a percentage of knock retard reduction per second

Index is engine RPM.

Table value formula: $ESC_Recovery = N \times 500/256$

[\$F3A1] If you look at the code the ECM executes for knock recovery, you'll see that to reduce the ESC Retard, it first multiplies the retard with the recovery amount to get the percentage amount. It then converts the percentage degrees to a negative number then *adds* this to the retard. Adding a negative number causes the retard to be reduced by the intended percentage.

In the example used earlier, 4.9 degrees of retard was applied to the advance because of knocks. If the advance was 24 degrees before the knock was detected, it would become 19.1 degrees. If no more knocks were detected, then 200 msec after the first one, the retard would be reduced 39% to 3 degrees. (Assuming the RPM is still near 4000.) This makes the total advance 21 degrees. The knock recovery continues until the retard is reduced to zero.

ESC Malfunction – Error code 43: [\$F3BC] Every 3.9 seconds, the ECM checks for a malfunction of the ESC (knock) components. It uses a counter (\$61) to tell when 3.9 seconds has elapsed. When the time is up, it reads the ESC PA count (\$0C0A) but only uses the high order byte. This number represents the total ESC count divided by 256. The ECM then subtracts the ESC count it read 3.9 seconds ago (\$60) from the count just read. If the difference is equal to, or greater than 143_{10} (\$2B5), it is considered to be an ESC failure (\$02 bit 1). The Malf 43 flag is set [\$F6A7] which turns on the Check Engine light.

Since the Malf43 code is only looking at the high order portion of the ESC PA, an increase of 143_{10} would actually be a total count of 36,608 (143×256). To achieve this in 3.9 seconds, the ESC input would have to be held low (0V) for 2.2 seconds. Actual detonation, no matter how severe, would never last this long.

Interpreting Scan Tool Displays for Knock: Most scan tools show two items related to knock detection: **Knock Count (\$5E)** and **Knock Retard (\$62)**. Some tools label the count **ESC Count**.

The Knock/ESC Count is most commonly mistaken as “the number of times the knock sensor has sent a pulse to the ECU.” *This is not so.* The Knock or ESC Count is the ESC PA count divided by 256. Just to review, the ESC PA count increases as long as the ESC input is low. (By the way, OEM knock detectors attach to this same wire.) A single knock could be a count of 10, or 75, or more. It takes 256 counts to make the scan tool Knock Count increase by 1.

Here is an example of 6 knocks detected and the displayed Knock Count is 2:

<u>Knock</u>	<u>ESC PA</u>	<u>ESC PA Delta</u>	<u>Knock Count</u>
1	75	75	0
2	190	115	0
3	390	200	1
4	540	150	2
5	600	60	2
6	625	25	2

The Knock Retard shown by the scan tool is the number of degrees the spark advance is retarded because of detonation. This is the total retard for all the knocks currently being processed and not necessarily the retard based on a single knock. As explained earlier, the knock retard for successive knocks is accumulative.

Summary: Here is an example of excessive knocking because the fuel mixture was WAY too rich. (Don’t ask me how I know.) See if you can tell when the individual knocks were detected. How many knocks were detected?

The ESC Cnt shown below is the number displayed on the scan tool. The frame numbers shown below are not consecutive frames, so the time between frames varies. The Retard shown is in degrees.

Frame	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Retard	0.6	0.3	0.9	1.4	1.0	0.7	1.4	2.0	2.5	1.8
ESC Cnt	1	1	1	2	2	2	2	2	3	3
Frame	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>
Retard	2.5	3.0	5.1	3.7	4.6	3.2	2.3	1.6	1.2	0.9
ESC Cnt	3	4	5	5	5	5	5	5	5	5

Frame 1 is certainly a knock. Frame 2 shows the retard has decreased, but Frame 3 has the retard going back up. This is due to the 2nd knock. In Frame 4, the retard goes up again so this is the 3rd knock. In Frame 5 and 6 it goes down (no new knocks). In Frame 7, 8, and 9, the retard increases each frame. This would be counted as three more knock events. The total (real) knock count so far is 6. Frame 10 shows the retard went down, so no new knocks. During these 10 frames, 6 knocks were detected and the scan tool displayed an ESC Cnt of 3.

Look at the last ten frames and see if you can spot the four frames showing more knocks detected. There are a total of 10 knock events during these 20 frames, but the scan tool ESC Cnt is 5.

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