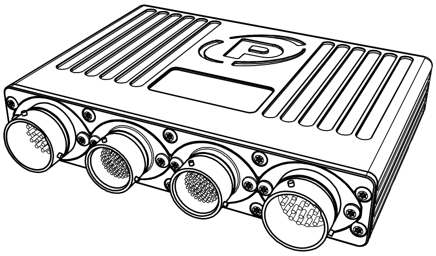
Pectel Control Systems

Application Note



Author: **John McKenna**

Last Editor: **Paul Andrews**

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Abstract: This document defines the use of the NR12 Knock Monitoring and Control strategies.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

Contents

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

1. INTRODUCTION

Knocking in an internal combustion engine is the uncontrolled self-ignition of the air/fuel mixture occurring midway through the combustion cycle, causing extremely high combustion pressure spikes that destroy pistons and rings in the engine. When the spark plugs fire too early, the fuel octane rating is too low, or carbon deposits inside the chamber grow hot enough to ignite the fuel, the fuel doesn't burn gradually -- it detonates all at once. This explosion sends out violent shock waves that vibrate the entire engine. Small amounts of knock are acceptable in a highly tuned engine, but the possibility of knock going into a run-away condition must be prevented.

Detection techniques include the use of sensors mounted on the engine block that will sense the high frequency vibrations generated by knock. Unfortunately, the vibrations created in the valve train are typically in the same primary frequency range as the knock signal. The placement of the sensors is critical to avoid as much valve train noise as possible and to be as sensitive to the knock vibrations coming from each of the cylinders. The vibrations from the valve train can cause a great deal of error in this system at high RPM, due to its inability to distinguish between valve noise and knock. Additionally each engine type will have different frequency characteristics.

By performing ignition control in a closed loop manner, the engine performance can be maintained close to its operating limits, or environmental limits, or simply those within the fuel type without engine damage. A closed-loop scheme measures the result of the actual ignition advance and maintains an optimal ignition advance setting in the presence of disturbances and general environmental conditions over successive knock events. A strategy is then put in place to reduce the level of knock before any partial or complete degradation of the engine performance. This normally involves ignition retard.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

2. OVERVIEW

This implementation replicates and extends functionality currently provided in the Pectel T10s ECU. The main points of difference are the use of an FPGA to carry out the digital signal processing and the strategies employed to determine and respond to knock intensities which require ignition angle changes.
There are 8 knock inputs supported. These are configured by the user and associated with individual cylinders.

2.1 Analogue Signal Conditioning

The analogue signals are conditioned in the following manner:

- Inputs are AC-coupled
- Analogue Band-Pass filtered : 5 – 25 kHz
- Selectable gain of 1 or 30, according to sensor type requirements
- 12-bit ADC sampled at 200 ks/s

2.2 Digital Signal Processing

The resultant ADC sample is processed in the following manner:

- Selectable angular sampling window is configurable to 0.1 Deg of crank rotation.
- Up to 8 band pass frequency selections can be configured on each input. Each filter is calculated in real time simultaneously.
- Each filter produces a peak, mean, integral and RMS value result.
- The weighting for each filter result is configurable, so that at the end of the sampling window the weighted sum is available for each cylinder.
- Final results are available almost immediately after a sampling window ends, this allows the configuration of very small or no angular gaps between windows, depending upon the maximum engine speed.
- Variations in individual sensors, the way they are mechanically fitted along with sensor positioning relating to each cylinder being measured, are accommodated with an individual gain selection for each cylinder sensor pair.

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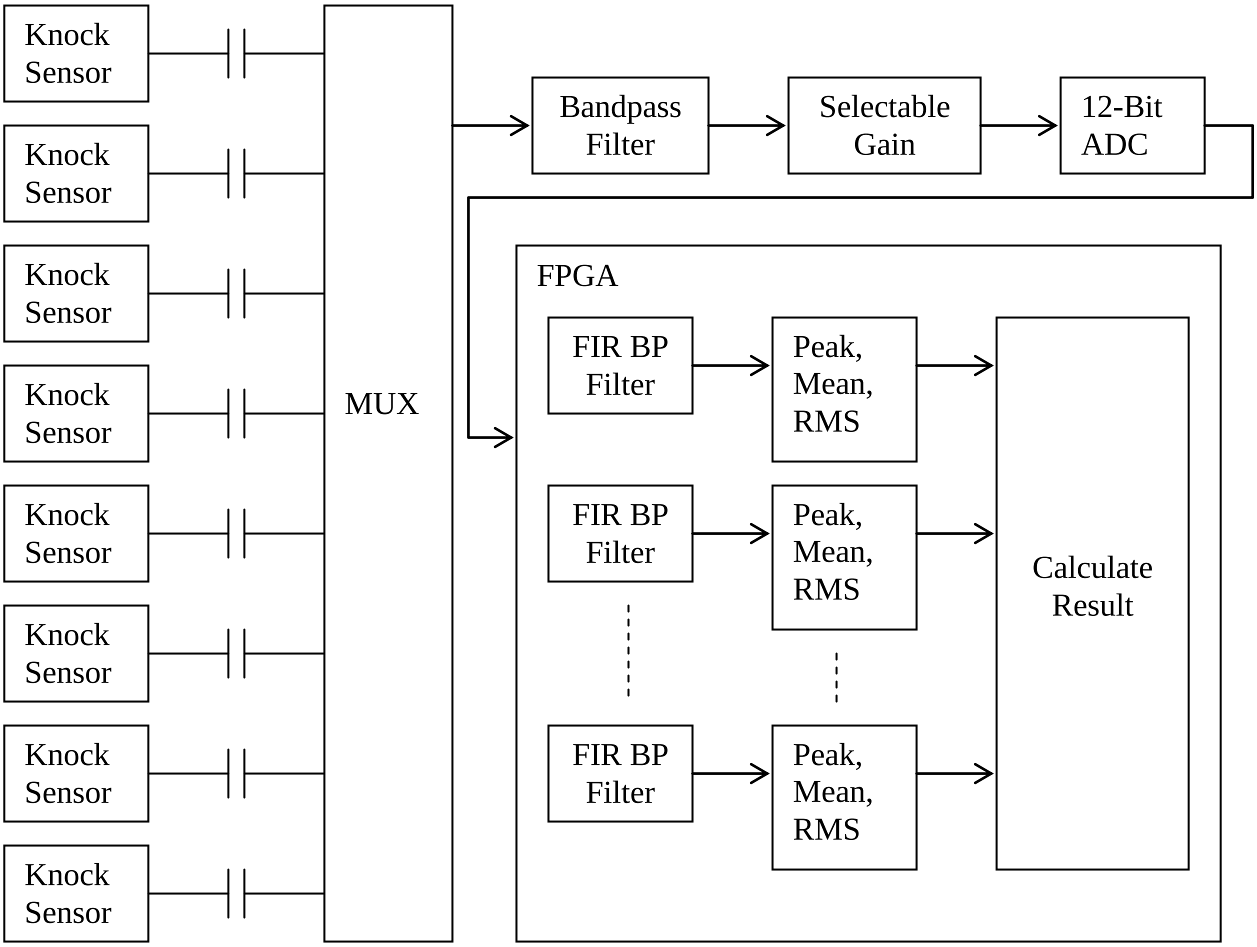
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601



Knock Monitoring Overview

This diagram provides an overview of the knock monitoring functionality provided by the FPGA.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

3. SIGNAL SAMPLING CONFIGURATION

The map configuration are presented as follows for configuring the knock sensors:

KNOCK CONTROL	
Control Strategy Enable	DISABLE/ENABLE
SIGNAL SAMPLING CONFIGURATION	
Input Amplifier Gain	1/30
DYNAMIC WINDOW CONFIGURATION	
Start Angle	90 to -90 Degrees
Width Angle	0 to 90 Degrees
Start Angle Engine Speed Breakpoints	RPM
FILTER CONFIGURATION	
Result Type	PEAK/MEAN/INTEGRAL/RMS
Number of Active Filters	1 – 8
Centre Frequency	5kHz to 25kHz per filter
Band Width	200Hz to 20kHz
Maximum Engine Speed	RPM
Filter Weightings	-1 to +1
Input Mapping	Cylinder 1 to Number of Cylinders
Cylinder Trim	0 to 2.0 per cylinder
Advanced Configuration Enable	DISABLE/ENABLE
ADVANCED CONFIGURATION	
Filter Size	1 to 255

3.1 Map Descriptions

The following descriptions provide more detail about each of the above maps.

3.1.1 Control Strategy Enable

When set to DISABLED none of the following knock control strategy is carried out. When set to ENABLED the signal sampling and monitoring results are calculated and valid map entries are required.

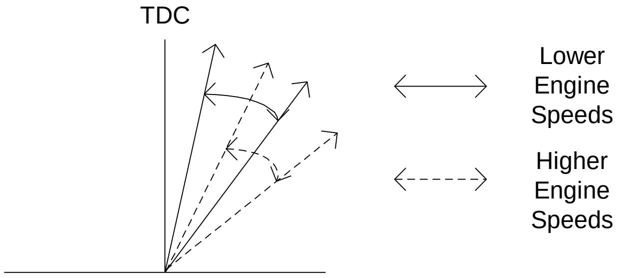
3.1.2 Input Amplifier Gain

This map allows the selection of the analogue input gain for all of the knock inputs, it should be selected according to the sensor source being used.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

3.1.3 Dynamic Windowing

These maps allow the configuration of the window of engine angular position at which the filtering of the input signals is to be applied. The input values are specified in relation to each cylinder TDC, in a similar manner to the ignition angle, to which it is closely related. Positive angles relate to those before the individual cylinder TDC, whilst negative angles relate to those after TDC.



Dynamic Windowing

Any asymmetry specified in the cylinder offsets as part of the general engine configuration settings will automatically be taken into account when applying these windows to individual cylinders. A check will be made that no start and end angles overlap and that a minimum computational window for the results at the highest engine speed are not exceeded, failure to meet this criteria will result in an error being reported and the engine will not start.
Dynamic windowing makes it possible to limit the likelihood of erroneous readings, by being able to take results over the narrowest window for the current engine speed, where the effects of knock are expected to be seen. A wider fixed window which covers the complete angular range for all speeds may pick up unintentional background effects.

3.1.3.1 Start Angle

This is the window start angle which will be used with all cylinders relative to their individual TDC. The angles will be interpolated between RPM breakpoints.

3.1.3.2 Width Angle

This is used to determine the end angle at each start angle, which will be used with all cylinders relative to their individual TDC.

3.1.3.3 Start Angle Engine Speed Breakpoints

This table of engine speeds will allow the user to move the window dynamically throughout the engine speed range.

3.1.4 Filter Result Type

The options are PEAK, MEAN, INTEGRAL or RMS. Only one result type for all inputs and all band pass filters can be selected. It is this value which is then applied to the weighted summation in determining the final monitoring value.

- The PEAK result represents the maximum peak value seen during the window.
- The MEAN result represents the average value seen during the window.
- The INTEGRAL result represents the summation of the absolute values (not signed) seen during the window.
- The RMS result represents the root mean square of the values seen during the window.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

3.1.5 Number of Active Filters

The number of filters to be applied to each of the knock inputs is configured here. The valid options allow from one to eight band pass filters to be applied to each input simultaneously.

3.1.6 Filter Frequencies

Each filter will have a centre frequency and band pass frequency range. These are individually configurable for each of the 8 filters, with the results applied to each knock input. The minimum and maximum frequencies permitted are determined by the analogue input filtering, these are 5kHz and 25kHz respectively. The minimum band pass frequency range is 200Hz. Frequencies can be entered in 100Hz steps.

3.1.7 Maximum Engine Speed

A check will be made on the window size specified and the maximum engine speed. If the filter size being used has insufficient samples available at the maximum engine speed, a warning will be displayed.
The options open to the user are to increase the window size, reduce the maximum engine speed at which results are taken, or reduce the size of the filter. This map is used to allow the ECU to determine if it should warn the user that their configuration may provide erroneous results above an engine speed.
See 'Advanced Configuration' for details on changing the default filter size.

3.1.8 Filter Weightings

This map configures the weighting to be applied to each configured band pass filter result. This allows free association with each frequency band with a significance given to the likelihood and severity of knock being present.

3.1.9 Input Mapping

This map allows the user to configure which knock input is associated with which cylinder. It will be possible to configure a free association with sensors and cylinders, on a one to one or one to many basis. Unused inputs should be set to DISABLED.

3.1.10 Cylinder Trim

This map will allow the user to apply a scaling factor to the individual sample measurements taken by a sensor each cylinder. This will allow compensation so that the results for each and every cylinder are normalised so that engineering tolerances in measurement results are compensated.

3.1.11 Advanced Configuration

An advanced configuration enable map will provide access to more advanced features of the knock configuration, initially providing only the means by which the number of points for each of the FIR filter kernels can be configured. The default number of points will be (129), which will provide sufficient performance up to (12,000 rpm and a 45 degree window).

Only odd numbered values can be entered in this map, as the filter kernel must be symmetrical around a centre tap, this restriction will be enforced by the profile. The maximum length will be 255.

As described in the 'Maximum Engine Speed' description, due to the nature of the implementation of the filter, sufficient samples are required within the required window otherwise erroneous results may be obtained. If a much higher engine speed or smaller window is specified, the default filter size can be changed, this will affect the frequency selection capabilities of the filter as a compromise.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4. STRATEGY APPLICATION

The previous section describes the way in which the signal sampling is configured, the next two sections describe firstly how the results of the sampling are used to provide the knock intensity and knock severity, as part of the monitoring configuration, then finally how these knock values can be used to control the ignition angle as a strategy.

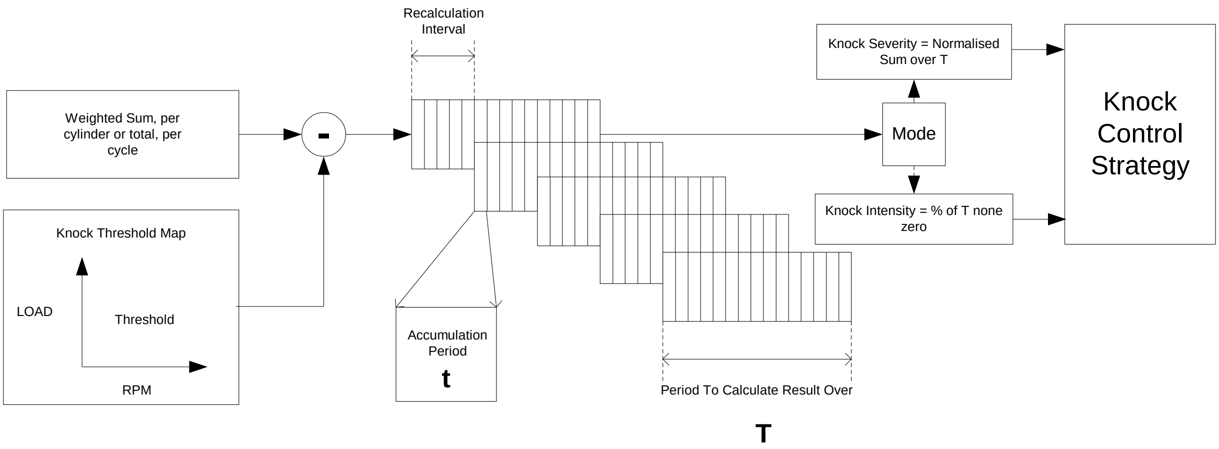
4.1 Monitoring

The knock monitoring stage has the following facilities. Two instances of monitoring can be configured, each works entirely independently, one is engine cycle based, and the other is time based.

The cycle based configuration is intended for knock determination over very short durations, measured in engine cycles, whose duration will therefore be dependent upon the current engine speed. Typically this method would be used for high knock intensities which could severely damage an engine in a short space of time.

The time based configuration is intended for knock determination over precise periods of time which can extend to a period of several minutes, allowing more general environmental conditions to be compensated for.

By populating the 'Knock Intensity Threshold' map with zero, it will be possible to monitor and log the baseline engine knock level in order to determine the threshold values required when carrying out ignition control when the strategy is enabled. Once the threshold values are populated, each cylinder will provide a result at each recalculation interval.



Knock Severity and Intensity Calculation

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.1.1 Map Descriptions
The following descriptions provide more detail about each of the map entries.

KNOCK MONITORING	
KNOCK THRESHOLD	
Knock Threshold	RPM V LOAD
INDIVIDUAL CYLINDER THRESHOLD	
Cylinder 1	V RPM
Cylinder 2	V RPM
……	
Cylinder 11	V RPM
Cylinder 12	V RPM
CYCLE BASED CONFIGURATION	
All Cylinder Measurement	DISABLE/ENABLE
Period To Calculate Results Over	cycles
Recalculation Interval	cycles
SEVERITY CONFIGURATION	
Normalisation Period	cycles
TIME BASED CONFIGURATION	
All Cylinder Measurement	DISABLE/ENABLE
Period To Calculate Results Over	time
Recalculation Interval	time
SEVERITY CONFIGURATION	
Normalisation Period	time
KNOCK MASKING CONFIGURATION	
Cycle Based Monitoring Mask Enable	DISABLE/ENABLE
Time Based Monitoring Masking Enable	DISABLE/ENABLE
Mask Time Extension After Ignition and Fuel Cuts	time

4.1.1.1 Knock Threshold

The single knock threshold map allows the user to configure the threshold above which knock of the desired level for the users strategy input is considered to have occurred. The levels specified in this map are compared against each cylinder after each window event against the cylinders' individually chosen weighted sum result type.

The operation of the knock threshold has been changed to incorporate the ability to provide a degree of fine tuning for an individual cylinder, these has been achieved by adding the individual cylinder threshold maps shown above. It should be noted that cylinder to cylinder variations should first be accommodated using the "Cylinder Trim" map found in the SIGNAL SAMPLING CONFIGURATION section within this document.

The affect of these additional maps, on an individual cylinder basis, is to compare the value from the "Knock Threshold" map against the individual cylinder threshold, the lowest value of the two, is used for each cylinder. If these individual cylinder maps are not to be used, they should have the maximum value permitted entered in the cell. Each map has an axis of engine speed matching the same breakpoints used in the common "Knock Threshold" map.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.1.1.2 All Cylinder Measurement

This map allows the user to select manually if the knock measurements are to be carried out for individual cylinders or summed together to provide a result over the recalculation interval for all cylinders.

When there is a sensor associated with the measurement of each individual cylinder, the user can decide manually. If they keep the individual cylinder measurement, when ignition control is enabled, each cylinder runs autonomously with its own control loop. If the all cylinder option is enabled, then all cylinder ignitions are modified with a global modifier by the same amount. It should be noted that due to the summation of multiple cylinders, it is likely the Knock Threshold map will need modification to remove the cumulative background noise.

If a sensor is not assigned to each and every sensor, then the all cylinder measurement mode is automatically enabled. This will sum the readings for each and every cylinder that can provide a measurement, over each recalculation interval, again this will affect the Knock Threshold required to remove background noise.

The all cylinder measurement can be chosen individually for TIME based and CYCLE based measurement, but the Knock Threshold map is common to both.

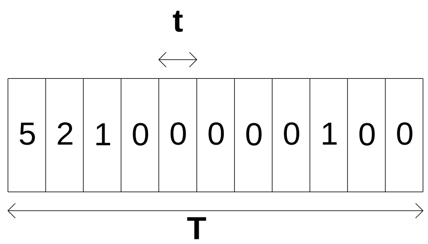
4.1.1.3 Period to Calculate Result Over

This map determines the period, either in number of cycles or time, over which a total knock severity and a knock intensity as a percentage result are to be calculated.

For a cycle based configuration, t will represent the result of each cycle, T will represent a buffer of results where the size of T will be directly configured by the map ‘Period To Calculate Results Over’.

For a time based configuration, t will represent a time determined from the configuration of T ‘Period To Calculate Results Over’ and the fixed internal buffer size, t = T/BufferSize. The minimum duration of t will be (1 ms), the buffer size will be (4096).

The total knock severity will be the sum of the values in each t, over the period T. The knock intensity percentage result, will be calculated as the percentage of T with none zero entries.
Example:



Total Knock Severity : 5+2+1+1 = 9 * Normalisation : sum of entries normalised
Knock Intensity = (4 / 11) * 100 = 36.36% : 4 entries of 11 are none zero.

4.1.1.4 Recalculation Interval

This map determines the rate at which new monitoring values of total knock severity and percentage severity are produced, either in numbers of cycles or time. The maximum value for this map is the ‘Period To Calculate Results Over’ with a minimum interval determined by either 1 cycle, 1mS or the fixed buffer size, depending on whether cycle based or time based monitoring is being configured.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.1.1.5 Normalisation Period

Two modes of operation for generating a knock value are available. These are knock severity and knock intensity modes. The severity mode provides a running sum value, normalised to a fixed period to aid calibration, this map specifies the normalisation period, in either cycles or time. At each recalculation period, the severity result obtained will be multiplied by the ratio of the 'Period to Calculate Result Over' to the 'Normalisation Period'.

Example : T = 20 cycles, Normalisation Period = 50 cycles. Sum = 27.

Knock Severity = 27 * (50 / 20) = 67.5

4.1.1.6 Knock Masking Configuration

It is required to provide some means of temporarily disabling the knock strategy when it is known that fuel and ignition cuts are taking place. This prevents the knock strategy being populated with inaccurate data, which has the potential to results in ignition changes which are inappropriate. Additionally, due to the transient nature of most of these events, they can result in an unsettling of the normal operation of the engine for an extended period after the cuts have taken place, again these may result in the knock control strategy taking inappropriate action.

The tools that have been provided are described next, it is up to the user to decide if they want to mask out these events, it may be decided that over a long period they are additional environmental factors which do need to be taken into account by the knock strategy.

It should be understood that the process of masking prevents both the monitoring and ignition control aspects of the knock strategy from operating. This permits the full range of applications to be controlled, and also ensures that logged parameters of severity and intensity reflect the application of ignition control during this masking period.

Feedback is required from support and customers to decide if further fine tuning of this implementation is required. The freezing of the strategy may result in the recovery operation, after an ignition retard application, being stalled, if it coincides with a torque reduction event. This stalling will last until the extension period has elapsed. This needs further consideration and testing.

This implementation guarantees the knock strategy will be masked for the whole period the torque reduction is requested, even when the extension period is zero. The masking and extension period are automatically applied for all torque reduction sources when enabled.

4.1.1.6.1 Cycle Based Monitoring

If the user wishes to enable masking during cycle based calculation, which is likely to be for short duration knock determination, then they should set this map to enabled.

4.1.1.6.2 Time Based Monitoring

If the user wishes to enable masking during time based calculation, which is likely to be for longer duration knock determination, then they should set this map to enabled.

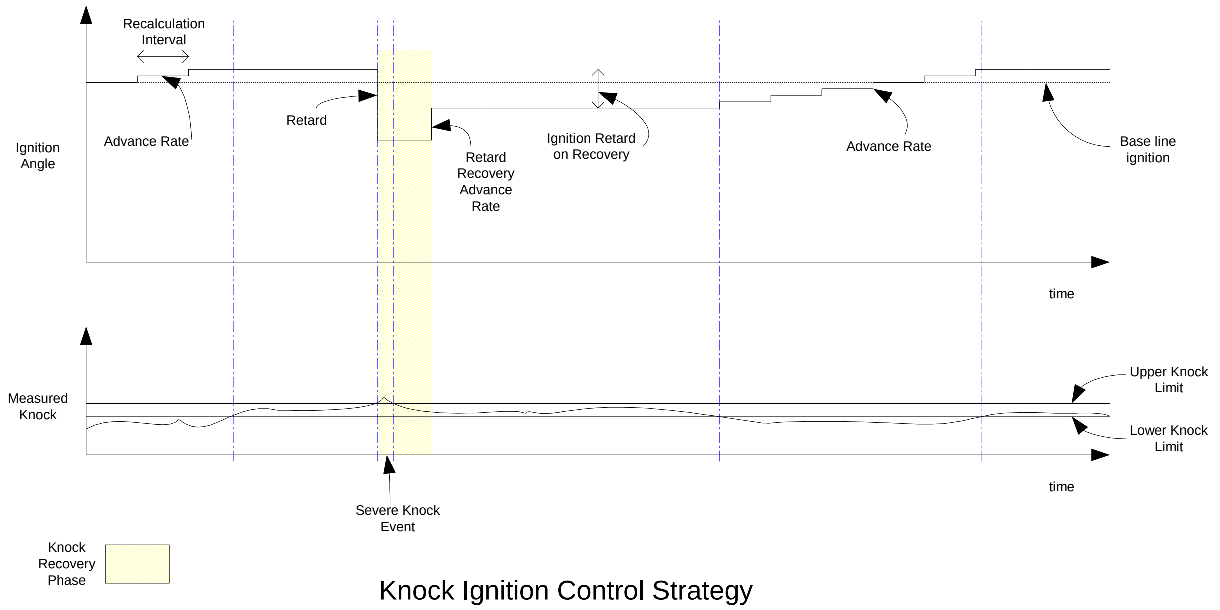
4.1.1.6.3 Mask Time Extension After Ignition and Fuel Cuts

After the torque reduction event has completed, there can be a significant change to the normal operation of the engine, due to a reduction of fuel for instance, which may provide unwanted indication of knock events. The user can therefore extend the mask time after each event using this single map.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.2 Ignition Control

The application of the knock intensity as a percentage will be used by an ignition control strategy to determine the current contribution to the final ignition angle.



Knock Ignition Control Strategy

The strategy compares the chosen knock mode result to two threshold limits, an upper and a lower. If above the upper limit, then a single instance of retard is applied at each and every recalculation interval. If below the lower limit then a single instance of advance is applied at each and every recalculation interval. If the current knock value is between these two thresholds there is a level of knock which is considered acceptable and no further modification of the ignition angle will take place.

When sufficient knock exceeds the upper threshold limit and the ignition is retarded, a recovery state is instigated. Instead of waiting for the normal ignition advance rate, which would pose an engine performance issue, a separate recovery advance rate is used which can be configured to a higher rate. Additionally, a target for the recovery ignition advance is latched which will be an ignition offset relative to the amount of advance achieved at the point at which the retard was applied. During the recovery state, the requirements for the lower limit threshold are ignored.

The advantages of this recovery method are as follows:

1. Lost power can be recovered quickly.
2. The knock event can be dealt with quickly by applying a relatively large ignition retard immediately the event is triggered, for a minimum duration of the recalculation interval.
3. A small advance rate in order to obtain the maximum performance from the engine can be configured, without having to compromise with the conflicting requirements when a knock event occurs.
4. If the reason for the knock event is a slower changing environmental one, poor fuel quality for instance, this strategy will allow the ignition to be reduced below the base map requirements and run continuously.
5. If the reason for the knock event is a more temporary short term effect due to driving within a poor quality air stream such as the exhaust gases of another vehicle, there will be the ability to reduce power and save the engine from damage within a short space of time, before recovering back to the peak performance level relatively quickly

The cycle based and time based strategies work completely independently.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
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It will be possible to control the lifetime of the learnt parameters as part of the knock control strategy. Each of the two ignition control types, cycle based and time based, will have an independent map that decides if the learnt ignition modification will be maintained outside of the active ignition control region. This will allow, for instance, a fast acting strategy, which uses cycle based timing, to always lose any learnt information as the engine moves outside of the active ignition control region. Whilst the time based strategy, which it is expected will provide longer term environmental modification, could remember its learnt ignition modification and apply it again when the active ignition control region is entered again.

4.2.1 Map Descriptions

The following descriptions provide more detail about each of the map entries.

KNOCK IGNITION CONTROL	
Ignition Control Throttle Angle Lower Threshold	Degrees
Ignition Control Throttle Angle Upper Threshold	Degrees
Ignition Control Throttle Angle Hysteresis	Degrees
Ignition Control Engine Speed Lower Threshold	RPM
Ignition Control Engine Speed Upper Threshold	RPM
Ignition Control Engine Speed Hysteresis	RPM
Ignition Control Ramp Rate	deg/cyl
Mask Time During Gear Change	mS
Strategy Reset Timeout	seconds
Strategy Reset Trigger	TRIGGER
CYCLE BASED CONTROL	
Cycle Based Ignition Control Enable	DISABLE/ENABLE
Calculation Mode	SEVERITY/INTENSITY
SEVERITY LIMITS	
Upper Knock Severity Limit	counts
Lower Knock Severity Limit	counts
INTENSITY LIMITS	
Upper Knock Intensity Limit	%
Lower Knock Intensity Limit	%
Ignition Retard Rate	Degrees
Ignition Retard on Recovery	Degrees
Maxmum Ignition Retard	Degrees
Ignition Advance Rate	Degrees
Ignition Advance Rate on Recovery	Degrees
Maximum Ignition Advance	Degrees
TIME BASED CONTROL	
Time Based Ignition Control Enable	DISABLE/ENABLE
Calculation Mode	SEVERITY/INTENSITY
SEVERITY LIMITS	
Upper Knock Severity Limit	counts
Lower Knock Severity Limit	counts
INTENSITY LIMITS	
Upper Knock Intensity Limit	%
Lower Knock Intensity Limit	%
Ignition Retard Rate	Degrees
Ignition Retard on Recovery	Degrees
Maxmum Ignition Retard	Degrees
Ignition Advance Rate	Degrees
Ignition Advance Rate on Recovery	Degrees
Maximum Ignition Advance	Degrees

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

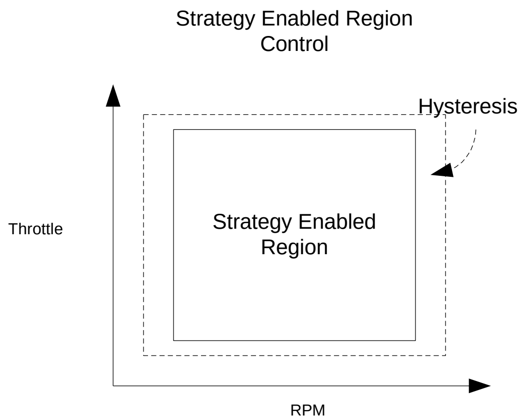
4.2.1.1 Ignition Control

This map enables the control of ignition using the following maps. When ENABLED all of the following maps must be populated with appropriate values.

4.2.1.2 Ignition Control Threshold and Hysteresis Functions

This selection of maps will allow the control of ignition from this strategy when within the throttle and engine speed ranges configured. When operating inside the region the strategy will continuously attempt to update the current ignition angle based upon the current knock level, when outside the region the strategy will be disabled and will therefore not contribute to the current value of ignition angle. Only ignition control is disabled, the sampling and monitoring continue as before and therefore may contribute to the algorithm after re-entering the enabled region depending upon how monitoring is configured.

Hysteresis is provided to restrict the rate at which the enable region limits are traversed, when operating close to the region edges. The hysteresis values will result in the inner enabled region having to be matched in order to become enabled, whilst the larger outer region will need to be exceeded in order to then become disabled.



The enable threshold must be less than the disable threshold, and the hysteresis regions must not overlap, otherwise an error will be indicated to the user.

On transition into and out of the strategy enabled region, the current level of ignition modification being generated by the strategy will be removed or introduced at the rate set by ‘Ignition Control Ramp Rate’.

When moving into the enabled state, until the previously learnt ignition adder amount has been achieved, strategy requests except for ignition retard are ignored. Upon determining that the level of knock requires ignition retard, then the ramping ceases and the normal strategy is applied based on the currently applied ignition adder.

When moving into the disabled state, all requests, including retard are ignored, as the strategy is outside of the control region, the ignition adder is reduced to zero, which may result in the overall ignition being advanced during this phase.

Further environmental modifications may be taken into consideration for enabling and disabling the strategy at a later date (TBD).

4.2.1.3 Mask Time During Gear Change

Any application of ignition retard for torque control purposes is going to be affected by the knock ignition control strategy, as it will become even more difficult to determine the level of retard to apply in order to obtain the desired effect. This map will allow masking of the ignition control strategy for a period.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.2.1.4 Strategy Reset Timeout

The user will be able to select the lifetime of learnt parameters from the knock control strategy. By setting this map to zero, the learnt parameters will never be cleared automatically on box startup, the user would need to use the manual method.

This map allows the user to specify the length of time the ECU must be without power before the learnt parameters are automatically cleared in seconds.

If one of the standard criteria for clearing none volatile memory are met, then the learnt parameters will be cleared as part of this operation, these criteria include loss/corruption of battery of backed ram, the loading of new code, but NOT the loading of a map.

If the user makes general ignition modifications, as a result of information gained from the knock strategy for instance, they should clear the current persistent learnt modifiers, as this will not be done automatically for them.

4.2.1.5 Strategy Reset Trigger

Once the calibration editor has been connected to the ECU for a minimum of 5 seconds, it will be possible to change this map entry and immediately reset the learnt parameters. This action results in a system message being displayed when the request is actioned. The engine must be stopped.

The value in the map is unimportant, it is the change in the value which triggers the clearing of data.
If the user makes general ignition modifications, as a result of information gained from the knock strategy for instance, they should clear the current persistent learnt modifiers, as this will not be done automatically for them.

4.2.1.6 Ignition Control Enable

The CYCLE based and TIME based modes of ignition control each have their own enable/disable map. By enabling that mode, both the mode specific maps and the strategy enable/disable region maps must be valid. These maps provide a means of preventing the totally independent ignition adders to be turned on and off.

4.2.1.7 Reset on Leaving Active Control Region

The CYCLE based and TIME based modes of ignition control will each have their own option to force the currently calculated level of ignition modification back to zero, each time the engine moves out of the region in which ignition control is active. The reset would be applied regardless of whether there is retard or advance being applied.

This means the user can control the persistence of the level of ignition control for each calculation type. If DISABLED, as the engine re-enters the active control region, the level of ignition modification will always return to the level previously learnt. If ENABLED, the level of ignition modification will always be zero.

This approach allows the user to limit the lifetime of the learnt ignition modifier for each control strategy. So that for instance, short term CYCLE based modifications can be forgotten quickly, potentially allowing return back to full power after being outside of the active region. Whereas longer term TIME based environmental modifications can persist.

4.2.1.8 Calculation Mode

Two modes of operation for generating a knock value are available. These are knock severity and knock intensity modes. The severity provides a running sum value, normalised to a fixed period to aid calibration, whilst the intensity provides a percentage value of the period in which knock exists.

See the monitoring section description in this document for an example of the modes.

4.2.1.9 Knock Limits

These limits will be used according to the ‘Calculation Mode’ selected, the entries are specific to the severity and intensity modes respectively.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

4.2.1.9.1 Upper Knock Limit

On each 'Recalculation Interval', if the calculated knock value exceeds this value, then the 'Ignition Retard Rate' will be applied, retarding the ignition because knock is considered prevalent. This action will be applied again on each and every interval until the limit is not exceeded when calculated for the 'Period to Calculate Results Over'.

The value of 'Upper Knock Limit' must be greater than the value of 'Lower Knock Limit' or an error will be reported and the engine will not start.

4.2.1.9.2 Lower Knock Limit

On each 'Recalculation Interval', if the calculated knock value falls below this value, then the 'Ignition Advance Rate' will be applied, advancing the ignition because knock is considered not to be prevalent. This action will be applied again on each and every interval until the lower limit is exceeded when calculated for the 'Period to Calculate Results Over', at this point a level of knock is considered to be present which will prevent further ignition advance, but does not require ignition retard to be applied.

The value of 'Upper Knock Limit' must be greater than the value of 'Lower Knock Limit' or an error will be reported and the engine will not start.

4.2.1.10 Ignition Retard Rate

This map sets the amount of ignition retard to be applied from the current ignition angle when the knock intensity exceeds the 'Upper Knock Limit'. This amount of retard will be applied at each 'Recalculation Interval' in which the knock value is above the limit.

4.2.1.11 Ignition Retard on Recovery (Offset)

Upon application of the ignition retard, the performance of the engine is likely to be reduced in order to prevent further knock events. During this recovery period a target ignition angle is latched which is an offset from the current ignition angle, and configured by this map.

This allows a different recovery rate to be used for recovering engine performance quickly, than would normally be used for general performance improvement, which is likely to be at a much lower rate.

4.2.1.12 Maximum Ignition Retard

This map sets the maximum amount of ignition retard that can be provided by the knock control strategy.

4.2.1.13 Ignition Advance Rate

Whenever the current level of knock intensity is below the 'Lower Knock Limit' the ignition will be advanced at this rate. This amount of advance will be applied at each 'Recalculation Interval' in which the knock level is below this limit.
Very low rates will be configurable for this map – 0.01 degrees, this is much lower than smallest angular change supported by normal ignition calibrations – 0.25 degrees, to provide greater precision and control over longer timescales..

4.2.1.14 Ignition Advance Rate on Recovery

In order to allow recovery of the engine performance at a faster rate than normally used for ignition advance, this map rate is used during the recovery period, until the ignition angle latched as described in the 'Ignition Retard on Recovery' map is reached.

During the recovery period, the 'Lower Knock Limit' map is ignored.

4.2.1.15 Maximum Ignition Advance

This map sets the maximum amount of ignition advance that can be provided by the knock control strategy.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
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5. KNOCK SENSORS

The use of knock sensors as part of an active control strategy for ignition modification requires consideration of failure modes. An FMEA (Failure Mode Event Analysis) has been carried out for this strategy to provide an assessment of anticipated failures, errors and their outcomes.

The main conclusion drawn from the analysis is that a means of determining whether individual knock sensors are functioning is required. This section details the configuration available to the user and the action taken upon failure. Each sensor will be compared against a user configurable threshold, whenever the knock control strategy is in the ACTIVE control region. These sensors are not suitable for simple static threshold detection as they are A.C. coupled, so the threshold used for comparison will be the R.M.S. sensor reading result. The error detection does not affect the readings taken for normal knock ignition control, but it does rely on the configuration used for measurement, as a result the user may find that their chosen failure detection threshold may need adjustment if they make changes to the monitoring section of the maps, for frequency, filter length etc.

For a sensor to be considered failed, level results must be measured which are consistently below the threshold, for a user configurable duration. If at any time the level results are higher than the threshold, the failure timer is reset. This process is performed on each cylinder, resulting in the user being informed which cylinder result has failed, along with the actual sensor providing the measurement having an error assigned on the errors page.

Upon failure detection, the knock control strategy is immediately disabled. Any ignition control is immediately removed, regardless of whether the individual or all cylinder ignition modifier is advanced or retarded. Simultaneously, the user configurable amount of retard on sensor failure is applied in its place. This process is not ramped for simplicity, as it is anticipated that the overall changes are relatively small. The registered errors will persist, along with the sensor failure ignition retard, until the box is reset. It will not be possible to recover the knock control strategy until the box has been reset.

It should be noted that the sensor failure ignition retard will only be applied during the normal knock control ACTIVE region, outside of this region, no ignition modification will be provided by the knock control strategy. All learnt ignition parameters will be zeroed on application of the sensor failure detection.

Failure to identify a failed sensor will naturally result in the knock control strategy advancing the ignition towards the maximum allowed which may result in engine damage.

5.1 Map Descriptions

The following maps are provided for the user to calibrate the detection of errors.

SENSOR ERROR DETECTION		
Sensor Error Limit		counts
Sensor Error Timeout	time	
Ignition Retard on Sensor Failure	Degrees	

5.1.1 Sensor Error Limit

Each cylinder configured to use a knock sensor is compared against this threshold whilst the engine is operating within the ACTIVE knock control region.

This limit is compared against the R.M.S. result of the configured knock monitoring parameters. The level found in the parameter “CylX_level_knk”, where X is the cylinder number, is the maximum value of “CylX_TotRMS“ seen within the previous 20mS period, for that cylinder.

Only cylinders configured with a knock sensor will be error checked. Setting a threshold of zero in this map will prevent this error checking strategy from detecting failed sensors.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham,
Cambridge, CB24 8PS, UK
Tel: +44 (0) 1954 253600 Fax: +44 (0) 1954 253601

5.1.2 Sensor Error Timeout

The knock sensor level "CylX_level_knk", will be compared against the threshold set in "Sensor Error Limit" for the duration configured in this map. The user needs to be considerate of the minimum engine speed and therefore maximum duration between none zero knock level results being available, otherwise false triggering of the error detection will occur.

The timer duration for each cylinder is reset whenever the engine moves outside of the ACTIVE knock control region.

Once an error is registered, is will not be possible to reset until the box is power cycled. All learnt ignition parameters are reset immediately on failure.

5.1.3 Ignition Retard on Sensor Failure

When a sensor has failed, the current level of knock strategy ignition modification is immediately replaced with the retard value entered into this map. This modification is applied as a global ignition modifier whenever the engine is operating within the ACTIVE knock control region.

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6. APENDIX 1

6.1 Raw Voltage Input

The channel Cyl#_Filt#_PosPk is the positive peak input value reading for a given filter for a given cylinder.

So assuming an ideal measurement, with a maximum input voltage measurable of 10V pk - pk, the result will be, for each selected frequency measurement (f):

Positive Peak = Measured Voltage x Cylinder Trim x Filter Weighting

$$\text{Cyl\#\_Filt\#\_PosPk} = \frac{\text{VinPk(f)}}{10} \times 32767 \times 1.000 \times 0.992$$

The final result is the sum of all filters configured, which is a maximum of N = 8.

POSITIVE PEAK SUM = SUM OF ALL FILTERS CONFIGURED (Measured Voltage X Cylinder Trim X Filter Weighting)

$$\text{Cyl\#\_TotPosPk} = \text{SUM N} \left[\frac{\text{VinPk(f)}}{10} \times 32767 \times 1.000 \times 0.992 \right]$$

This means that if there were no losses in the measurement, a 10V pk input signal would provide a result of 32767 for each filter which matched the input frequency of the signal. A -10 pk input signal would provide a result of -32767 for each filter which matched the input frequency of the signal.

Cosworth Electronics, Brookfield Technology Centre, Twentypence Road, Cottenham, Cambridge, CB24 8PS, UK
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7. USER NOTES

Some additional help may be available in the map by pressing ‘F1’ on the keyboard.

For further help and for all other enquires please contact Pectel Customer Support.

Pectel Control Systems,
Brookfield Motorsports Centre,
Twentypence Road,
Cottenham,
Cambridge,
CB4 8PS,
UK.

Tel; +44 (0) 1954 253610,
Fax; +44 (0) 1954 253601.
Website; http://www.pectel.co.uk
Email; support@pectel.co.uk