LPC8 ECU

-

REFERENCE MANUAL

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Contents

1 Introduction

LPC4 is an engine management system for spark ignition engines,
capable of sequential fuel injection and ignition on 4 cylinder
engines, bank fire and waste spark or distributor spark on engines
with up to 8 cylinders. In addition to the more common four
stroke engines, two strokes and Wankel type engines are supported
as well.

LPC8 is an evolution of the LPC4 that adds sequential fuelling
and ignition for up to 8 cylinders as well as more sensor inputs,
including but not limited to an integrated wide band lambda
sensor controller for Bosch LSU sensors and inputs for two knock
sensors. On the LPC8, internal data logging and real time clock
is standard fitment, but an option on the LPC4. The LPC8 also
has electronic throttle control support standard while the LPC4
requires an add-on board for that.

It must be noted that many aspects of the configuration and
strategies are also documented inside the configuration file. If
you push F1 while editing a variable in the Calibrator application,
you will get context sensitive help related to the category you
are editing.

2 Wiring

2.1 Pin-outs and description

2.1.1 Pin numbering

(a) Connector A

(b) Connector B
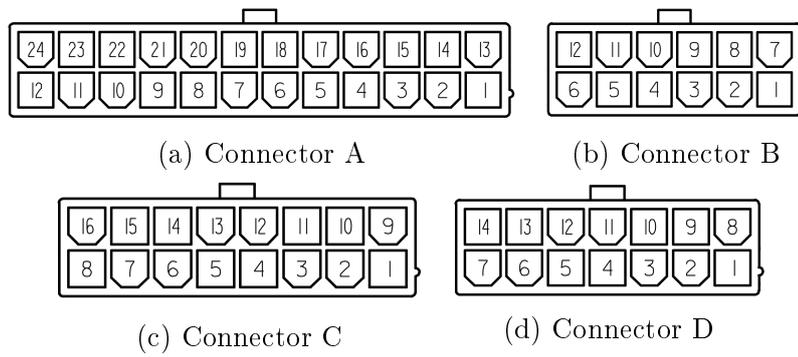

(c) Connector C

(d) Connector D

Figure 2.1: Pin numbering of the different connectors on the back of the controller. Note that the connectors are not oriented as shown but the locking tabs face inwards.

2.1.2 Connector A pin-out

Pin	I/O	Function	Note
1	OUT	5V sensor supply	200mA max
2	IN	Analog 0 0-5V - TPS (APP A in ETC mode)	100kΩ pull-down
3	IN	Analog 1 0-5V (APP B in ETC mode)	51kΩ pull-up
4	OUT	Ground return for analog sensors	
5	IN	Analog 4 0-5V	51kΩ pull-up
6	IN	Analog 5 0-5V	51kΩ pull-up
7	IO	CAN H	120Ω termination
8	IO	CAN L	120Ω termination
9	OUT	Output 1 (Tach out)	Low-side switch, 5A max, 1kΩ pull-up to 12V
10	OUT	Output 2 (Fuel pump relay)	Low-side switch, 5A max
11	IN	Power ground	
12	IN	Power ground	
13	IN	Digital input 1	Active low, 5.7kΩ 5V pull-up, 12V safe
14	IN	Analog 2 - Coolant temperature sensor	3kΩ pull-up
15	IN	Analog 3 - Charge air temperature sensor	3kΩ pull-up
16	OUT	Ground return for crank/cam sensors	
17	IN	Cam sync input	2.2kΩ pull-up default
18	IN	Crank trigger input	2.2kΩ pull-up default
19	IN	Digital input 5	Active low, 5.7kΩ 5V pull-up, 12V safe
20	OUT	Ground for signal shields	(or extra power ground)
21	OUT	Output 4	Low-side switch, 5A max
22	OUT	Output 3 (PWM idle)	Low-side switch, 5A max. Clamping diode to supply pin.
23	IN	Digital input 2	Active low, 5.7kΩ 5V pull-up, 12V safe
24	IN	Switched +12V supply	Internally fused

2.1.3 Connector B pin-out

Pin	I/O	Function	Note
1	OUT	Output 5 (PWM idle anti-phase)	Low-side switch, 5A max
2	OUT	Output 6	Low-side switch, 5A max
3	OUT	Ignition 5	5V logic, 15mA max. May be configured as extra injector output at order time instead.
4	OUT	Ignition 6	5V logic, 15mA max. May be configured as extra injector output at order time instead.
5	OUT	Ignition 7	5V logic, 15mA max. May be configured as extra injector output at order time instead.
6	OUT	Ignition 8	5V logic, 15mA max. May be configured as extra injector output at order time instead.
7	OUT	Output 7	Low-side switch, 5A max
8	OUT	Output 8	Low-side switch, 5A max
9	OUT	Ignition 1	5V logic, 15mA maximum current sourced
10	OUT	Ignition 2	5V logic, 15mA maximum current sourced
11	OUT	Ignition 3	5V logic, 15mA maximum current sourced
12	OUT	Ignition 4	5V logic, 15mA maximum current sourced

2.1.4   Connector C pin-out

Pin	I/O	Function	Note
1	IN	Knock sensor 1	
2	IN	Knock sensor 2	
3	IN	Lambda sensor nernst voltage	Connect to pin 6 of LSU4.9 sensor
4	OUT	Lambda sensor virtual ground	Connect to pin 2 of LSU4.9 sensor
5	IN	Analog 10 0-5V	51kΩ 5V pull-up default, software selectable 2975 Ω
6	IN	Analog 8 0-5V	51kΩ 5V pull-up. Throttle position A when using ETC.
7	IN	Analog 12 0-5V	51kΩ 5V pull-up.
8	OUT	Ground return for analog sensors	
9	IN	Digital input 4 (vehicle speed typical)	Active low, 11kΩ 5V pull-up, 12V safe
10	OUT	Lambda sensor pump current	Connect to pin 1 of LSU4.9 sensor
11	IN	Lambda sensor trim resistor	Connect to pin 5 of LSU4.9 sensor
12	IN	Digital input 3	Active low, 11kΩ 5V pull-up, 12V safe
13	IN	Analog 11 0-5V	51kΩ 5V pull-up default, software selectable 2975 Ω
14	IN	Analog 9	51kΩ 5V pull-up. Throttle position B when using ETC.
15	NC	NC	Analog 15 if no internal barometric pressure sensor is fitted
16	OUT	5V sensor supply	200mA max, shared with other 5V outputs

2.1.5 Connector D pin-out

| Pin	I/O	Function	Note
1	OUT	Throttle H bridge output 1	Positive in forward (opening) direction. 15A max current
2	OUT	Injector 1	Low-side switch, 5A max
3	OUT	Injector 2	Low-side switch, 5A max
4	OUT	Injector 3	Low-side switch, 5A max
5	OUT	Injector 4	Low-side switch, 5A max
6	OUT	Lambda heater	Low-side switch, 5A max, connect to pin 3 of LSU4.9 sensor
7	IN	Power ground	Join with wires from pins 11 and 12 of connector A no more than 150mm away from controller.
8	OUT	Throttle H bridge output 2	Positive in reverse (closing) direction. 15A max current
9	OUT	Injector 5	Low-side switch, 5A max
10	OUT	Injector 6	Low-side switch, 5A max
11	OUT	Injector 7	Low-side switch, 5A max
12	OUT	Injector 8	Low-side switch, 5A max
13	IN	+12V supply for H bridge	Not protected, use external 15A fuse. Only connect if using electronic throttle.
14	IN	Power ground	Join with wires from pins 11 and 12 of connector A no more than 150mm away from controller.

2.2 Wiring diagrams
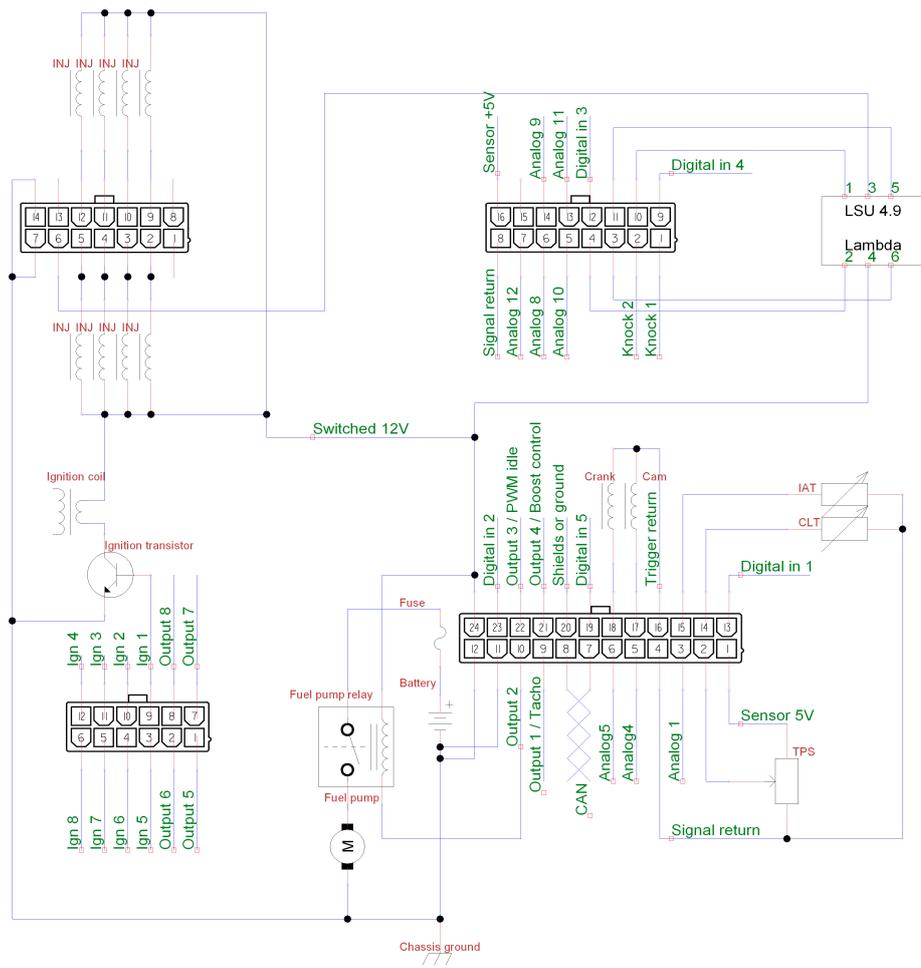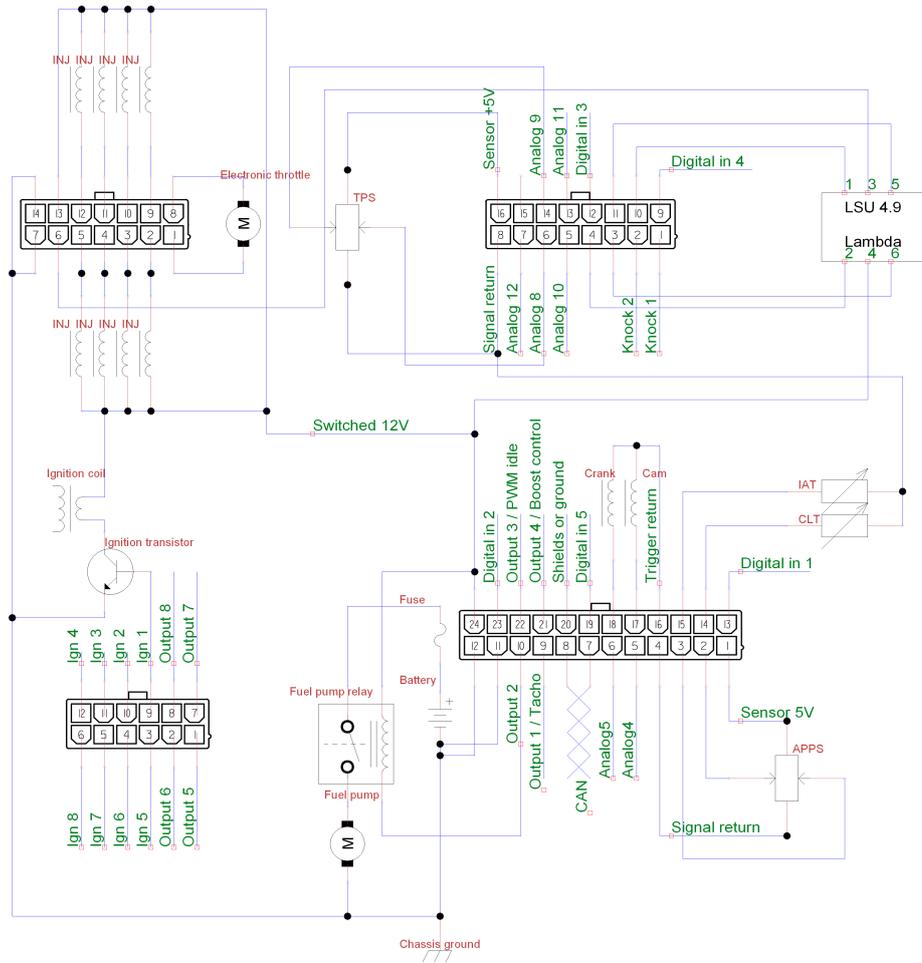

Figure 2.2: Typical basic wiring

Figure 2.3: Typical wiring with electronic throttle.

2.3   Wiring guidelines

2.3.1   Grounding

The controller should be connected to the battery negative terminal or another reliable grounding point by at least a pair of $1.5mm^2$ wires or a single $6mm^2$ wire joined to smaller wires near the connector. The controller requires 4 ground wires, connected to pins 11 and 12 of connector A and pins 7 and 14 of connector D. These 4 ground wires must be joined together no more than 150mm away from the controller. From this joint you may connect the ground wire(s) that go to the battery or cylinder head. An improper ground connection will cause electrical noise and possibly faults with controller operation. If utilising factory wiring, joining all of the supply ground wires for the original ECU should suffice.

2.3.2   Engine speed sensors

The inputs on the controller for crank/cam sensors are of schmitt trigger logic type, with 2.2kΩ pull-ups and with over-/undervoltage protection diodes. Thus they may be connected directly to open-collector or logic sensors (Hall effect, optical) or variable reluctance sensors. Some poorly designed VR sensors have an output voltage too small at cranking speeds for reliable starting, for those an amplifier module must be installed in the controller.

2.3.3   Ignition outputs

The LPC8 has eight 5V logic-level outputs current limited to 15mA. To utilise those outputs requires either ignition coils with internal igniters or an external ignition transistor module. If your engine has neither, a good cost effective transistor module for up to 8 coils may be purchased from `https://controls.is/itm8.html`

2.3.4   Idle control

The LPC8 supports three types of idle control valves. 2 wire PWM, 3 wire PWM and 6 wire stepper. 4 wire stepper can be handled by fitting pull-up resistors to each wire. A value of 15Ω and 2W has been shown to work well on the common GM/Chrysler valves. A 2 wire PWM valve must be connected to output number 3. A 3 wire PWM valve uses outputs 3 and 5 to drive each coil. Stepper valves can be connected to any of the outputs but usually outputs 5 through 8 are used, arrangement of the wiring does not matter as it can be configured in software. When using electronic throttle control, a dedicated idle control valve is typically not necessary or desireable, but is supported by the controller firmware nonetheless. If not using the electronic throttle for idle control, simply set the idle control authority in the electronic throttle section of the configuration to zero.

2.3.5   Electronic throttle control

In electronic throttle control mode, the accelerator pedal connects to pins 1 through 4 on connector A and throttle position sensors on the throttle body connect to pins 6 and 14 on connector C as well as shared sensor ground and sensor 5V supply. It is not recommended to share the ground path or 5V feed for the accelerator pedal with any other sensor.
The electronic throttle motor connects to pins 1 and 8 of connector D, in current direction that opens the throttle, positive voltage will be supplied from pin 1 and negative from pin 8.
The throttle driver bridge needs a $+12V$ supply feed to pin 13 of connector D. An in-line fuse rated 10-15A is recommended to protect the circuit.

2.3.6   Lambda sensor

The LPC8 includes a controller for one wide band lambda sensor. Calibration is provided to run Bosch LSU 4.9 sensors but if you are able to create your own calibration data, other LSU sensors as well as certain NTK sensors may be used.

For LSU4.9 sensors, no calibration is typically necessary as the sensor's trim resistor is used for reference.

LSU 4.9 pin	Function
1	Pump current, pin C10 on ECU
2	Virtual ground, pin C4 on ECU
3	Heater negative, pin D6 on ECU
4	Heater positive, 12V power when ECU is powered
5	Reference resistor, pin C11 on ECU
6	Nernst voltage, pin C3 on ECU

Figure 2.4: Bosch LSU4.9 sensor wiring

2.3.7 Programmable outputs

The ECU has eight programmable outputs and while all low speed functions are applicable to every output, some PWM functions have dedicated outputs. This means that if those functions are used, they can only be assigned to the specified output. Outputs 1, 3 and 4 provide high accuracy PWM capability, with events timed to the nearest microsecond and a maximum PWM frequency of 2000Hz. Outputs 5 through 8 provide lower accuracy PWM capability with microsecond timing but possible timing error of individual pulses up to 100 microseconds. Maximum frequency on those outputs is 200Hz and although average error is on the order of zero, due to the nature of these software driven outputs occasional pulses may be out by as much as 100 microseconds. The exception is output 5 when in PWM idle anti phase mode, where it is driven at full 1 microsecond precision.

Function	Output
Tachometer output	1
PWM idle control	3
PWM idle anti-phase	5

Figure 2.5: Functions with dedicated outputs

3   Software configuration

Refer to BG calibrator manual for introduction to the software.
The default configuration file has the following defined keyboard
shortcuts:

Key	Function
F5	Edit main fuel map
F6	Edit main ignition timing map

3.1   Crank/cam trigger configuration

The LPC4 and LPC8 ECUs have a unique way of dealing with
crank/cam trigger signals. This enables it to decode a large
variety of different trigger arrangements without needing the
firmware to specifically support each arrangement. As a consequence
the configuration of the trigger inputs may seem confusing to
first time users. To combat this, presets are provided for common
configurations, see the presets dialog in the calibrator software
and check if your engine is listed.

In this chapter, the primary (or only) trigger is always referred
to as the crank trigger, despite the possibility of the reluctor or
shutter wheel being driven from the camshaft. The primary/cam
filter periods let the ECU ignore any event occurring within a
certain amount of time since the previous event. Useful against
certain types of noise in certain trigger arrangements. Must
be set to a lower number than the shortest anticipated event
interval at maximum engine operating speed.

The modes of trigger input operation are as follows:

Basic Single impulse on crank trigger input for each cylinder's
firing event. Works for configurations that only require a

single ignition output, either single cylinder, multi cylinder with distributor or multi cylinder running all cylinders in waste spark configuration. Also useful if no ignition control is required.

Versatile multi tooth The highly versatile crank/cam decoder for variable reluctance type crank sensors or hall effect setups where all the information required is available by decoding only one type of signal edge (rising or falling, not both).

Dual edge A variation of the versatile multi tooth decoder where alternating teeth defined are alternating polarity (rising or falling, starting with whichever is defined as the crank trigger active edge).

Duty cycle coded A variation of the versatile multi tooth decoder that triggers on one edge type (rising or falling) but measures the duty cycle, the ratio between high and low state. A pattern can then be entered denoting the duty cycle of past previous pulses and when that pattern is matched, the decoder generates a sync event. This arrangement is used on the earlier generation GM LS type engine (24X trigger) but this mode can also be configured to decode some Chrysler crank triggers.

Log only A mode that does not enable running an engine but does let one capture an event log of the crank/cam inputs without fuel being injected or ignited.

3.1.1 Basic trigger

This mode has only three configurable options. The trigger angle offset whose useful range would be from zero up to the angle between firing events. (90 degrees on a 4 stroke V8 f.ex). The crank trigger active edge and the pulses skipped when starting options are also used. Cam sync, trigger teeth and other options not used. Primary trigger filter period does apply.

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3.1.2 Versatile multi tooth decoder

The basic operating principle of the versatile multi tooth decoder
is that each tooth sensed by the crank angle sensor is defined
by the crank angle that separates it from the previous tooth
before it. The crank angle of the first tooth in the cycle (aka
trigger angle offset) in degrees before top dead centre cyl 1 is
also defined, cyl 1 being assumed to have an angle offset of zero
in the cylinder angle table. The trigger angle offset can have a
value of anywhere from zero to 719 degrees. Used in conjunction
with the tooth gap table is also a tooth repeat table. The tooth
repeat table saves the user from having to configure multiple
tooth entries where a number of adjacent teeth all have the same
spacing. As an example a 36-1 crank trigger wheel only needs
two tooth entries. 20 degrees and 10 degrees, and in that case
the repeat values are 0 and 33 as the first tooth of the 35 that
are present only occurs once, zero repetitions are performed.
The second tooth and the 33 teeth that follow it have the same
tooth spacing so a value of 33 is used for the second repeat value.
From knowing the angle of the first tooth and the spacing of
every tooth from the previous one, the decoder can calculate
engine speed as well as crank angle every time an event occurs
on the crank trigger input, but this information is not enough to
let the decoder find its reference point in the cycle. To find the
reference point and start decoding from tooth one, there are a
number of strategies available. At the time of writing they are as
follows:

None In this mode, cam sync is relied upon entirely for crank
angle reference. In this mode, there must be enough teeth
defined to cover the entire cycle so if there are 12 teeth on
the crank, the tooth config must account for 24 teeth or
sync is deemed lost before the next cam sync opportunity.

Missing tooth In this mode, the decoder compares the spacing
of adjacent events and if the interval between events exceeds
the interval of the previous event by a configurable threshold
(typically at least 1.5), the current event is deemed to be
tooth one and crank decoding can start. In this mode, the

first defined tooth must have its defined angle greater than the other teeth.

Extra tooth In this mode, the decoder compares the spacing of adjacent events and if the most recent interval is shorter than the previous interval by a configurable threshold (typically no more than 0.7, preferrably less) then that tooth is ignored and the next event following it is deemed tooth one and decoding can start. There is a very good reason why the extra tooth is ignored in the code. For one, having extra crank angle resolution at one part of the cycle is of little benefit, but if the exact angle of the extra tooth is not known then it would be very detrimental to engine control to include it in the decoder output. Therefore, in this mode, the extra tooth must not exist in the tooth definitions, the first tooth is the tooth following the extra tooth.

Two adjacent long gaps is used for 36-2-2-2 and similar configurations where the sync is found by detecting two adjacent gaps that are wider. (One tooth, two missing, one tooth, two missing again, for example.) In this strategy the sync threshold ratio is multiplied with the last tooth before the two big gaps, the previous two intervals must be bigger than the result and the interval before the referenced interval must also be smaller than the result to register sync.

Double check missing tooth takes the last interval (before the current tooth), multiplies by the threshold and both the current interval and the interval before the previous one must be shorter than the result. This is the recommended mode to use for most 36-1 and 60-2 and similar triggers. Note that in this mode the first tooth in the teeth table is the second tooth after the gap in the trigger wheel.

If a cam position sensor is present, there are a number of different strategies available to decode that. The behaviour of the cam sync differs if a crank sync strategy is configured or not. When a crank sync strategy is configured, the cam sync will not apply unless crank sync has been found, and when that happens the

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crank angle will be set to the correct phase according to the angle offset of crank tooth #1. If no crank sync strategy is selected, then the cam sync will apply immediately.
The cam sync strategies are the following:

Cam state on crank sync This mode is useful for hall effect or similar logic output cam position sensors with a single wide tooth (half moon type). In this mode, the cam signal is not logged and no interrupts are generated on edge events but instead the state of the cam signal is polled when a crank sync event happens (missing tooth, extra tooth). If the cam input is in a logic low state (less than 1 volt input) then the configured angle offset is applied and full sync mode is entered. If the cam input is in a logic high state, then the configured angle offset is applied, shifted by 360 degrees and full sync mode is entered.

Count cam impulses This mode is useful for all types of sensors and applies to cam wheels with as little as a single tooth but also applies to more complex arrangements. In this mode, every event on the cam input increments a counter but every event on the crank input reads the counter and resets it to zero. If the counter value matches the configured cam sync count, then cam sync is applied at that crank event and full sync mode is entered.
An example where this mode is used is the Subaru 6/7 pattern, where a series of two or three cam impulses can be used to determine the crank angle and cam phase.

Count crank impulses This mode applies to certain crank/cam patterns where there are two or more cam teeth unevenly spaced or a greater number of evenly spaced cam teeth with some oddly spaced crank teeth. A counter is incremented on every crank event but read and reset on every cam event. If the counter matches the configured cam sync count then the following crank event will apply the cam sync. An example where this mode applies is Cosworth YB where the cam sync has two teeth spaced at 180 degrees of crank rotation.

Primary trigger is cam This mode allows the use of a missing tooth or extra tooth trigger wheel rotating at cam speed so the reference tooth angle is correct and no extra cam position information is required for full sync operation.

Crank state on cam impulse This mode only applies to dual-edge trigger decoder mode, used to decode DSM/Miata/Neon trigger. Has a configurable option for what the crank state must be for the cam event to register. The crank event following the cam event is deemed tooth number one.

Cam count pattern Principally the same as count cam impulses mode, except instead of comparing only the current value of the counter every crank event, a configurable number of previous values are also considered. This is useful if the cam wheel has an insane amount of oddly spaced teeth, such as seen on early Chrysler/Jeep 4.7 V8.

3.1.3 Dual edge trigger

A mode for logic type sensors only (hall effect or optical). This mode is operationally identical to the versatile multi tooth trigger except that alternating teeth are expected to occur on alternating edges, with the first tooth occurring on the configured active edge for the crank trigger. Examples that use this include the Mitsubishi 4g63 and Mazda Miata, where it is used with cam sync.

3.1.4 Duty cycle coded trigger

A mode for logic type sensors only (hall effect or optical). This mode is operationally identical to the versatile multi tooth trigger except that the crank sync mode selector is not used. Instead it is hard coded to use a duty cycle pattern to sync. Normal trigger operation only happens on either a rising edge or a falling edge and the period since the last opposite edge divided by the period since the last active edge is the duty cycle. In the pattern, a value of 1 matches a duty cycle greater than 50% and a value of zero matches a duty cycle less than 50%. The pattern can

have up to 8 positions. The typical use of this trigger mode is the GM LS1 engine, where it allows reliable operation with or without cam sync.

3.1.5 Equal spacing missing tooth

This is a trigger mode that can be used interchangeably with versatile multi tooth on simple missing tooth setups (36-1 or 60-2 for example), with the possibility of ignoring the teeth on either side of the gap in the pattern if they prove to be imprecise in timing.

3.2 Internal data logging

The LPC8 controller includes 8GB or more logging memory as well as a real time clock to time stamp the log files with time and date of when logging started. Data recorded at the highest available logging rate (500Hz) will take up around 10 megabytes per minute. At the time of writing the download rate is around 3 megabytes per minute so a 10 minute data log recorded at the highest rate would take around 30 minutes to download from the controller. To keep log sizes small without compromising on log resolution, burst mode is provided, where the logging rate can be kept low normally but accelerated during conditions that command it, such as when at full throttle.
Data can only be downloaded when a log isn't being captured and the engine isn't running. For that reason it is recommended that the controller is configured to not start recording until engine speed reaches some non-zero number, except for testing of the logging function itself. Once logging is started, it will continue until the controller is powered off or a stop condition is triggered.
It is important to note that the binary format of the log files changes when the firmware is updated, so old logs can be downloaded but will not convert correctly to bglog format when the configuration file open in the Calibrator application does not match the firmware that recorded the log.

3.3   Performing firmware upgrades

Whenever new features are introduced, new firmware becomes available for download at `https://controls.is/firmware/`. See the release notes if you are unsure of whether you should update or not. To perform a firmware upgrade:

1. Download firmware package from web site

2. Unzip firmware package into a directory on your hard drive

3. Connect USB cable between ECU and PC.

4. Power on ECU, do not start engine.

5. If you do not have the configuration backed up, run BG Calibrator, read configuration from ECU and save to file. This step may be skipped if you are performing the upgrade on an ECU you haven't made any previous configuration changes to.

6. Run `upgrade.cmd` in directory where firmware files are located.

7. Wait until the upgrade application finishes, should be on the order of 10 seconds.

8. Power ECU off.

9. Do not power ECU back on until you are ready to upload configuration to it.

The ECU has been upgraded but now contains invalid configuration. If you are proceeding with default configuration, simply open the default configuration file for the new firmware in BG calibrator and go on-line, then send local settings when prompted about what to do with the ECU side configuration. Otherwise, if you wish to retain your previous configuration, which is generally recommended, perform the following steps:

1. Run the BG Calibrator software

2. Open your old configuration file

3. Select `File -> Convert configuration` from the menu bar.

4. Select the configuration included with the new firmware in the file dialog.

5. The configuration has now been converted to the new format, save it and exit the Calibrator software.

6. Run the Calibrator software again and open the configuration file you saved previously, choose to work off-line.

7. Review the settings and verify that they make sense, see release notes for information about what settings may need revisiting.

8. Go on-line and power on the ECU. Do not start engine.

9. When prompted, select to use local settings, which will then be uploaded to the ECU.

After the configuration has been sent to the ECU and Calibrator application becomes responsive again, power the ECU off and then back on. Now you can start the engine.

A   Real time data fields

The descriptions of all the real time data fields have been moved into the configuration file as of firmware version 1.15. They can be read in the dialog for configuring the real time display or exported to a text document from Calibrator.