PNP12

4 LED Plug and Play Sequential Shift Light

Operation Manual

www.firmtec.co.uk

EMC/EMI Compliance Statement: CE Mark Declaration of Conformance

This product conforms to the following specifications:

- EMC: EN55022
- Safety: EN60950
- Immunity: EN55024
- This product complies with European Directive 1995/5/EC.

Manufacturer's Disclaimer Statement

Contents

1.1 Introduction

The Firmtec Sequential Shift Light was designed primarily for motorsport applications allowing for no compromise in performance and reliability. Giving the driver a clear visual indication of the approaching rev-limit allows for perfectly timed gear changes resulting in maximum performance. Performance gained by optimising the gear change alone yields valuable 'tenths' per lap adding up to many seconds per race and that's not including the gains from allowing the driver full concentration on the road and not the rev-counter. The Firmtec Sequential Shift Light has 3 high brightness Light Emitting Diodes (LEDs) which light sequentially over the user-defined rev band preceding the shift point. This gives the driver the chance to anticipate the shift point, without having to concentrate on a rev-counter, and the final ultra bright shift light confirms the precise moment at which the next gear is required.

The latest version of the Firmtec Sequential Shift Light uses sophisticated Digital Signal Processing (DSP) techniques to analyse the vehicle electrical system. From this data the shift light is able to calculate vehicle engine speed with only a simple two-wire connection to the vehicle wiring loom. Connection through the cigar lighter socket is sufficient on most vehicles making the Firmtec Sequential Shift Light a truly plug and play device.

The Firmtec Sequential Shift Light has two operating modes; DSP and Tacho. In DSP mode the Firmtec Sequential Shift Light performs a spectrum analysis on the vehicle electrical system to derive engine speed and requires a simple two wire/cigar lighter connection. In Tacho mode the Firmtec Sequential Shift Light is connected like a conventional shift light to the vehicle tachometer drive or ignition coil. In this mode the user has more precise control over the first 3 LEDs.

Quiescent Current (Standby):	<1mA
Maximum Current (4 LED):	85mA
Minimum Operating Voltage:	9V
Maximum Operating Voltage:	16V
Processor:	32MHz RISC MCU (8MIPS)
DSP Technique:	Fast Fourier Transform (up to 60kHz)
Accuracy:	Better than 10rpm*
Maximum Engine Speed:	up to 18000rpm*

*tacho mode only

2.1 Installation

2-wire Plug and Play

The Firmtec Sequential Shift Light requires only a simple a two-wire connection to the vehicle. It is supplied with a standard 12v accessories/cigar lighter connector for easy connection to the vehicle and is ready to be used as soon as it is plugged in.

Alternative Tachometer Connection

For more precise control of the shift light the standard plug can be removed exposing three wires (+/GND/TACH) for connection to the vehicle tachometer drive or ignition coil. It is recommended that the device be connected to a 'switched' supply which operates on the ignition switch – especially when fitted to vehicles which are not in regular use. **It is essential that the positive supply is *not* connected directly to the positive side of the ignition coil as this terminal experiences high voltage spikes which could damage the device and give erratic operation.**

The signal wire, coloured blue, should be connected to the switched Low Tension (LT) connection of the ignition coil (typically indicated with a (-) sign). There is normally a connection to this terminal found on the vehicle dashboard wiring loom. If this is not the case the signal wire will need to be extended and connected directly to the coil. On distributor-less ignition systems this wire can be connected to any one of the switched LT connectors. Typically on distributor-less ignition systems there will be a large diameter positive supply wire with two slightly smaller diameter switched wires. The blue wire should be connected to either one of these.
Alternatively the blue wire can be connected to the tachometer drive output. **This is essential on Capacitive Discharge Ignition (CDI) systems**.

It is recommended that 'snap-lock' connectors are used to connect the cable to the vehicle wiring loom. Alternatively soldering directly to the existing cabling is also acceptable. Any poor connections will result in erratic operation of the unit and may cause flickering of the LEDs. Please refer to **Figure 1** and **Figure 2** for schematic diagrams.

Red:	12V + VE (e.g. Battery (+) terminal)
Green:	0V Earth (e.g. Vehicle Chassis or Battery (–) terminal)
Blue:	Signal Wire. Connect Directly to Coil LT (-)/Tach terminal

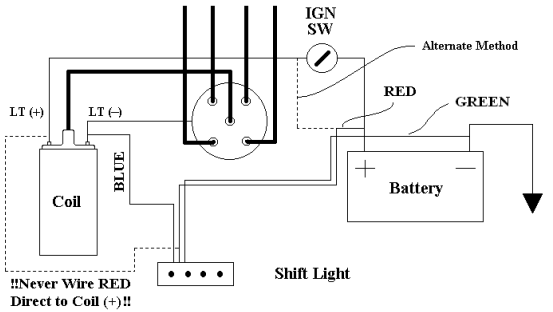


Figure 1. Conventional Ignition Wiring Diagram

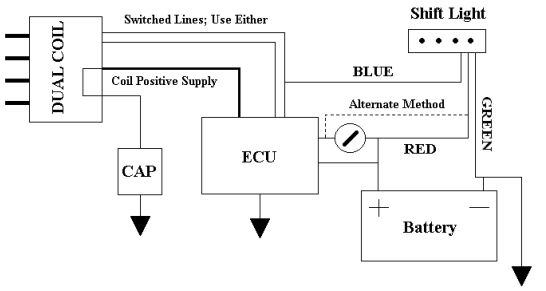
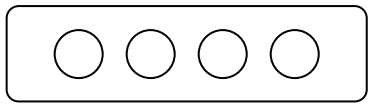


Figure 2. Wasted Spark Distributor-less Ignition Wiring Diagram

3.1 Setup and Usage



L1 (Blue)	L2 (Blue)	L3 (Blue)	L4 (Red)
DSP Mode	Calibration Mode	Tacho Mode	Tacho Mode WS

Table 1: Ignition type setup

When the unit is first powered on the current setup is indicated by the flashing LEDs as shown in **Table 1**.

The operating mode is changed by pressing the set button once whilst the current mode is being displayed (LED flashing at power-up).

DSP Mode

This mode makes use of the 2-wire plug and play setup and is the default mode for the shift light. The shift point can be set using Method 1 (Half Engine Speed) or Method 2 (Digital Set). However, for digital set to be accurate in DSP mode the shift light must first be calibrated using Calibration Mode.

Calibration Mode

This mode is selected to calibrate the shift light for DSP mode or to make use of the Auto Setup function in Tacho Mode. For further detail see Calibration/Auto Setup

Tacho Mode

This mode is used to make use of the three wire setup. It allows for more accurate control of L1, L2 and L3 and does not require calibration. However, it is important to first select the correct engine type (number of cylinders – see Configuration Parameters) or to run the Auto Setup function.

Tacho Mode WS

This mode is intended for use when connected to a 'Wasted Spark' type coil pack. It is included to remain compatible with legacy devices but is **not recommended for general use**. If the vehicle engine is a 4-cylinder WS type and the TACH connection is connected to a coil then this mode can be used with the default settings for an instant setup.

3.2 Setting the Shift Point

There are two methods of setting the shift point engine speed. Generally Method 1 is used as an approximate setting (and to set the rev-band if required) and Method 2 is used for accurately setting the shift point.

Method 1: Half Engine Speed

Method 1 can be used in both DSP and Tacho modes. With the engine running, press and **hold** the SET button (the LED will light after 2 seconds to show set mode has been entered). Raise the engine speed to **half** that of the shift point and allow the engine speed to settle. Once the engine speed is stable the SET button is released and the desired shift point engine speed is set. It should be noted that at engine speeds above 1250rpm (**Tacho mode only**) the red LED (L4) will light indicating the minimum engine speed setting (shift point – 2500rpm) has been reached. If this is not the case check setup and installation.

If setting the shift point has been successful the LED RPM gap is now set. By pressing the SET button once, the current setting can be changed and is shown on the LEDs. Once the desired setting is displayed the SET button is held until all LEDs are extinguished. This stores the new interval setting. This interval setting is also used when setting the shift point digitally using Method 2.

In DSP mode the exact RPM gap between LEDs is not accurately configurable. L1 gives the minimum gap between LEDs and L4 gives the maximum.
In Tacho mode the gap can be set to 50rpm (L1), 100rpm (L2), 150rpm (L3) or 200rpm (L4). For example, if set to 200rpm the LED prior to the shift point, L3, would light at 200rpm less than the shift point LED (L4). L2 would light at 200rpm less than the L3 engine speed and so on. This would give a total rev-band of 600rpm from the first LED (L1) to the shift point (L4).

Example: Setting the shift point to 6000rpm

Hold engine speed at 3000rpm and press and hold SET. LED L1 will illuminate to show set mode has been entered and in Tacho mode the red LED L4 will illuminate to show the minimum engine speed (1250rpm) has been

reached. Release the SET button. The shift point has now been set to 6000rpm.

In Tacho mode to set an interval of 200rpm the SET button should be pressed repeatedly until the red LED L4 is illuminated. In DSP mode this would give the maximum RPM gap. The SET button should now be held until all LEDs have been extinguished. The setup is now complete. The following should now be observed whilst driving:

5400RPM **5600RPM** **5800RPM** **6000RPM**

Method 2: Digitally Entering a Shift Point

Method two allows the user to accurately define a shift point between 1000 and 9990rpm. This can be done with the engine on or off in DSP or Tacho modes but not in calibration mode.
Digital set mode is entered by double clicking the SET button which will illuminate all LEDs.
The LEDs will then display a binary value starting at 0 (all off) and will count up to nine and back to zero, incrementing by 1 every second. Table 2 shows the binary to decimal conversion however it is not necessary to know or recall this information as the user can simply count from zero to the desired number value each time the display changes.
The thousands digit is entered first followed by hundred and tens. To select a digit the SET button is pressed when the corresponding value is displayed on the LEDs.

For example, in DSP or Tacho Mode, double click the set button to enter digital set mode. After the LEDs have extinguished, the display will start incrementing from zero (all off) to nine. To set the shift point engine speed to 6250rpm count up from zero (all off) to 6 (off, on, on, off) and click SET to select the thousands digit. The display will be held for two seconds to confirm the selected digit. After this the display will continue counting so that the hundreds digit can be selected. If the desired digit is missed the display will roll-over back to zero and can be selected the next time it is displayed. When the number '2' is displayed (off, on, off, off) the button is clicked and this will be shown on the display for 2 seconds. Finally the tens digit can be selected in the same manner. The shift point is then stored and normal operation is resumed.

○ ○ ○ ○	Zero	● ○ ○ ○	One (Red)
○ ● ○ ○	Two	● ● ○ ○	Three
○ ○ ● ○	Four	● ○ ● ○	Five
○ ● ● ○	Six	● ● ● ○	Seven
○ ○ ○ ●	Eight	● ○ ○ ●	Nine
○ ● ○ ●	Ten	● ● ○ ●	Eleven
○ ○ ● ●	Twelve	● ○ ● ●	Thirteen
○ ● ● ●	Fourteen	● ● ● ●	Fifteen

Table 2: Binary Code

3.3 Switching off the Display

To switch off the Firmtec Sequential Shift Light the SET button is given one short press with the **engine running**. The red shift light will be seen to flash 3 times indicating that the unit is entering standby mode. By pressing the SET button one more time the unit will return to normal operation, indicated by the Blue L3 LED flashing 3 times.

4.1 Configuration Parameters

The Firmtec Sequential Shift Light features an in-built configuration menu for advanced options. The shift light can be operated fully without accessing this menu which is provided for extra flexibility (firmware v4.06 or greater). The menu is accessed using the digital set mode by setting the 'thousands' digit to zero (0). For example, to change the engine type to 6-cylinder, the value 0, 4, 6 is entered in the digital set mode.

x1000	x100	x10	Range	Description
Mode	**Item**	**V**		
0	**0**	**0**		Reset to Defaults
0	**1**	0-14	(V+1) x 50 RPM	LED3/LED4 Rev Difference
0	**2**	0-14	(V+1) x 50 RPM	LED2/LED3 Rev Difference
0	**3**	0-14	(V+1) x 50 RPM	LED1/LED2 Rev Difference
0	**4**	0	4	Engine Type: 16cyl
		1	1	1-cyl or one coil per plug
		2	2	2-cyl (parallel twin)
		3	3	3-cyl
		4	4	4-cyl (**default 4**)
		5	5	5-cyl
		6	6	6-cyl
		7	10	10-cyl
		8	8	8-cyl
		9	12	12-cyl
0	**5**	0-14	(V+1) x 8us	Hysteresis Value (**default 4**)
0	**6**	0-14	(V+1) x 0.25ms	Filter Coefficient (**default 2**)
0	**7**	0-7	*(see notes)*	DSP LED Gap (**default 1**)
0	**8**	0-14	0 – 14 Pairs	Number of Poles (**default 6**)
0	**9**	0-3	0 – 3	Operating Mode (**default 0**)
0	**10**	0-14	0 – 15	DSP Sensitivity (**default 7**)
0	**11**	0-14	0 – 15	Sample Rate Crossover (**default 4**)
0	**12**	0-1	0 – 1	3rd Harmonic Test (0 – Off, **1 – On**)
0	**13**	0-1	0 – 1	Extra Sample Bank (**0 – Off**, 1 – On)

Table 3. Configuration Parameters

System Reset (Option 0)

To reset the Firmtec Sequential Shift Light to factory defaults, using digital set mode, a value of 0, 0, 0 is entered. This can also be achieved by holding the SET switch whilst the current setup is being displayed during power up. Please note holding the switch during initial power up will result in the 'stuck switch' error being displayed.

Default values are as follows:

Engine type: 4-cyl
LED Gaps: 100RPM
Hysteresis Value: 4
Filter Coefficient: 2
DSP LED Gap: 1
Alternator Poles: 6
Operating Mode: 0
DSP Sensitivity: 7
Range Cross: 4
3rd Harmonic Test: On
Extra Sample Bank: Off
Tacho Engine Speed: ~2500RPM
DSP Engine Speed: ~3000RPM (2.60 Pulley Ratio)

LED Gaps (Tacho Mode Only) (Option 1-3)

Individual LED rev differences can be set using this option. The minimum value of zero corresponds to 50RPM and increases by multiples of 50 RPM with the value entered (max. 750RPM).

Engine Type/Number of Cylinders (Option 4)

This option is used to set the number of engine cylinders and is used in Tacho mode to calculate the shift point and LED gaps.
If the TACH connection is made to the ECU tachometer output then this value is typically set to the number of cylinders of the engine.
If the TACH connection is connected directly to an ignition coil then this value is the number of cylinders that the coil is used for. For example, with a conventional 4-cylinder, single coil, contact breaker points setup, the coil supplies all 4 cylinders. In this case the Number of Cylinders is set to 4. In a modern engine which makes use of a wasted spark type coil pack each coil typically supplies just 2 cylinders. Hence in this case the Number of Cylinders would be set to 2.
If the user is having trouble setting up this option then the Auto Setup function should be used in calibration mode to determine this value.

Hysteresis Value (Option 5)

Hysteresis is an engineering term used to describe the 'one-wayness' of a system. There is a small amount of hysteresis programmed in to the shift light to account for minor variations in the timing of the ignition system. The shift

light will illuminate at the set engine speed whereas it will extinguish at a slightly lower engine speed – the difference being controlled by the hysteresis value. Please contact support@firmtec.co.uk for further details. A high hysteresis value may be required on some 'V' engines due to the offset in timing between cylinders.

Filter Coefficient (Option 6)

This value can be adjusted to change the latency of the input and should be minimised to ensure adequate response to high engine speeds. If the shift light regularly flickers at engine speeds below that of the set point this value may be increased (try starting at 1, incrementing by 1). If the shift light does not respond to high engine speeds this value may be reduced down to 0. Please contact support@firmtec.co.uk for further details.

DSP Mode LED Gap (Option 7)

This value sets the relative gap between LEDs in DSP mode when using the digital set function. Please note the RPM gap is larger at higher engine speeds than at lower engine speeds. A value of 0 may correspond to approximately a 30RPM gap at 3000RPM whereas this would be approximately 60RPM at 6000RPM.

Number of Poles (Option 8)

This value corresponds to the number of 'claw poles' in the vehicle alternator. Typically an automotive alternator has 6 poles, which is the default value. See Calibration Mode for further details.

Operation Mode (Option 9)

This is an alternative method for setting the operating mode of the shift light.

0	DSP Mode
1	Calibration Mode
2	Tacho Mode
3	Tacho Mode WS

DSP Mode Sensitivity

This option sets the Global Fourier Energy Limit for the device. The energy level of each frequency in the spectrum is analysed and this value sets the minimum energy level a signal must reach to be considered valid. See Optimisation for information on how to use this control.

Range Crossover

The Firmtec Sequential Shift Light has two DSP operating modes optimised for low and high engine speeds. This value controls the crossover set point which is typically around 4000RPM by default and is optimum for most engines.

Third Harmonic Test

Setting this option to 1 enables the third harmonic test and setting it to zero disables the test. A harmonic is an integer multiple of a signal such that it's measured frequency would be $n \times f_q$ (n is the harmonic, f_q is the fundamental frequency). A pure, noise free signal would provide considerable energy for a circuit tuned to it's third harmonic and appears as a peak on a spectrum analysis plot. The third harmonic test is used to determine whether the energy at this frequency is caused by a fundamental or a harmonic however this analysis adds to the workload of the processor. See optimisation for more details.

Extra Sample Bank

Setting this option to 1 enables the additional memory bank to be used and setting to zero disables the additional memory bank. The voltage of the electrical system of the vehicle is rapidly sampled and stored every 3µs (microseconds) and analysed thereafter. The extra bank option enables an additional memory allocation for storing data; however this creates additional workload for the processor. See optimisation for more details.

5.1 Calibration

For the digital set functions to work accurately the unit must first be calibrated.

DSP Mode

The primary source of electrical noise in the vehicle electrical system is caused by the alternator. The alternator is a 3-phase alternating current generator which is rectified and regulated to DC at 14.4v. As it is an alternating current device it produces energy at a certain frequency proportional to engine speed and the number of 'claw poles' within it. The alternator is typically driven faster than the engine and the ratio of alternator speed to engine speed is equal to the ratio of the large crankshaft drive pulley to the smaller alternator drive pulley.

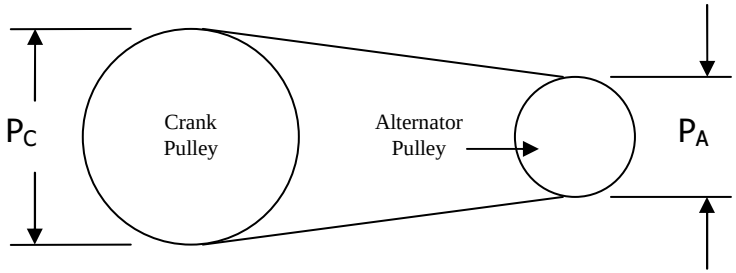
There are two ways of calibrating the shift light for DSP Mode. The unit can measure the alternator output frequency at a specific engine speed (3000RPM) or the user can specify the pulley ratio and number of claw poles (typically 6). This information is available on the Firmtec website for certain vehicles or can be physically measured on the vehicle.

Engine Speed Sampling

The easiest way to calibrate the shift light is to measure the alternator frequency at a known engine speed. To do this calibration mode must be selected (L2 flashing on power up). To calibrate the shift light, press and **hold** the SET button. LED L3 will display after 2 seconds. When the engine is at **precisely 3000RPM**, release the SET button. The recorded data is now analysed (this may take up to 2 seconds) and if the operation is successful the red LED L4 will flash to confirm this. If the blue LED L3 flashes this indicates that the operation was not successful and should be tried again. If repeated attempts at calibration fail you may need to set up an exclusion list (see Exclusion List for details).

Entering Pulley Ratio

In calibration mode (L2 flashing on power up), the digital set function sets the pulley ratio only. **No other configuration options are available in this mode.**



Pulley Ratio = P_C / P_A

Example

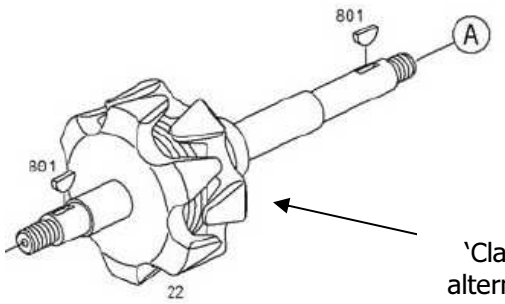
If the Crank and Alternator Pulleys measure 13cm and 5cm respectively, the Pulley Ratio is equal to:

13.0/5.0 = 2.60

This is entered using the digital set function in a similar way to entering a shift point engine speed. To enter this ratio, in calibration mode, the SET switch is double clicked to enter the digital set function. 2.60 would be entered as 2, 6, 0 (as if setting the engine speed to 2600RPM). The shift light will automatically exit calibration mode and return to DSP mode on completion.

Number of Claw Poles

You can often see the number of claw poles within the alternator through the outer casing (see **Figure 3**). This is the number entered using configuration parameter option 8. Most vehicles have a 6 pole alternator. Note this value must be entered outside of Calibration Mode as only pulley ratios can be entered whilst in this mode.



'Claw Poles' – This alternator has 6 pairs

Exclusion List

If shift point setting Method 1 or calibration repeatedly fails you may need to set up an exclusion list. This stops sources of electrical noise from equipment other than the alternator (such as HID lighting, ECUs, fans etc…) being analysed. In calibration mode this is done by clicking the SET switch with the engine at idle and the equipment switched on. During the test the display will count down from 9 to 0. During this time the user may also rev the engine to exclude certain engine speeds from analysis. Contact support@firmtec.co.uk for further details. A system reset clears the exclusion list.

5.2 Auto Setup

Auto Setup is used with the 3-wire Tacho Mode to set the number of engine cylinders. If the shift light is connected to a coil LT wire, then it can be difficult to determine how many cylinders the coil will fire for. Auto Setup will measure the time between pulses at a known engine speed and determine this automatically. It can tolerate some inaccuracy in the rev-counter which does not affect the overall accuracy of the shift light.
To utilise Auto Setup, enter Calibration Mode (L2 flashing on power up) and hold the engine at 3000RPM. Press and hold the SET switch (L3 will light as per the DSP calibration). When the engine speed is stable at around 3000RPM release the SET switch. The shift light will now calculate the number of engine cylinders. If successful L1 will be seen flashing alternate with the DSP calibration result LED and the shift light will return to Tacho Mode (L3 flashing on power up). If L2 flashes then the setup could not be determined on this occasion. If neither L1 nor L2 was seen to be flashing then no TACH connection was detected during the test (check wiring). Do not use Tacho Mode WS with Auto Setup.

6.1 DSP Optimisation

By default, in DSP mode, the Firmtec Sequential Shift Light is optimised for rapid response at high engine speeds. On engines with high angular acceleration (the rate at which the revs rise) the shift light may respond poorly or not at all (particularly at low engine speeds) if additional processor resources are required by the third harmonic testing, extra memory banks and the 3us sampling rate (controlled by range cross value).
To increase response rates the user may disable the extra memory bank and third harmonic test. Changing the range cross value is not recommended. Disabling the 3rd harmonic test may cause the shift light to respond to engine speeds 1/3 that of the set speed (e.g. 2000rpm when set to 6000rpm). This can be 'tuned out' by gradually increasing the DSP Sensitivity.

To increase stability the extra bank option may be enabled which by default is disabled. For most vehicles the additional required processor resources will not negatively affect overall performance. If the shift light appears to randomly respond to various engine speeds the DSP sensitivity may be increased slightly. If the gap between the LEDs is noticeably uneven or inconsistent the DSP sensitivity may be slightly decreased.

7.1 Fault Finding

Issue	Problem	Solution
DSP Mode		
No power	Blown fuse	Check fuse in cigar lighter plug and vehicle
All LEDs flash on startup	Stuck Switch	Release switch
No response (DSP mode)	Sensitivity	Reduce Config Parameter 10 (default 7)
Poor response	Sensitivity	Reduce Config Parameter 10 (default 7)
Flicker throughout range	Sensitivity	Increase Config Parameter 10 (default 7)
Flicker throughout range	Sensitivity	Switch on extra RAM bank Config Param 13
Response at RPM/3	Third Harmonic	Switch on Third Harmonic Test Config Param 12
Response at RPM/3	Third Harmonic	Increase Config Parameter 10 (default 7)
Tacho Mode		
No power	Blown fuse	Check fuses and wiring
All LEDs flash on startup	Stuck Switch	Release switch
Flicker throughout range	Input Filter	Increase config param 6 (start @ 0, inc by 1)
No response at high revs	Input Filter	Increase config param 6 (by 1, down to 0)
Flicker between LEDs	Hysteresis	Increase hysteresis filter config param 5
Wrong set point	Nº of Cylinders	Run Auto Setup

Table 4. Fault Finding

We hope you enjoy using this product as much as we enjoyed developing it!

Developed and Manufactured by
Advent Controls Ltd, Liverpool, UK
Made in UK