

### Features and Benefits

- Low cost - minimal external components
- In PDIL8, PSOP8 or Chip-on-board
- 50/60Hz operation
- Robust digital design:
  - Offering stable triac control
  - Eliminating variations due to changes in analogue parameters
  - No aging and temperature influences
- True PI speed regulator
- No external calibration or adjustment required
- Low power consumption
- Suited for driving resistive and inductive loads
- Pulse input to measure the motor speed with a low cost coil or a hall sensor
- Motor current sensing for power limitation
- Adaptable to specific motor and application requirements by mask programming

### Applications

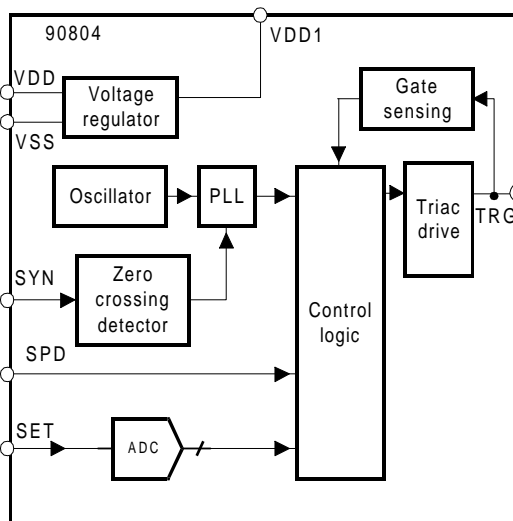
Universal motor control applications that require true speed regulation, such as used in blenders, mixers, kitchen appliances, drills, etc

### Ordering Information

Part No.	Temperature Suffix	Package	version	Temperature Range
MLX90804	S	A	-x	0C to 85C Automotive

The customer specific version code (defining the options) is indicated with 1 character at the end of the ordering number.

### Functional Diagram



### Description

The MLX90804 is a power control IC for controlling the speed of AC motors by means of a triac. The speed setting is done by applying a ratiometric voltage at pin SET (usually by means of a potentiometer). This speed setting is compared with the pulse rate at the SPD input. The input is compatible with inductive and magnetic detectors. The calculation of the required phase angle is done with a PI regulator, which is fully digital. A soft start function is implemented to eliminate high current peaks at startup. Also available are an overload and overspeed protection. The build in Frequency Locked Loop compensates for variations in the mains frequency giving a stable frequency independent trigger control. Several parameters can be adjusted by mask programming: minimum and maximum speed, soft start delay, gain settings of the PI regulator, ...

## **General Description**

### **Speed Regulator**

The speed is regulated by a PI regulator with programmable parameters Kp and Ki.

### **Speed Measurement**

The speed is measured either by a coil or by a hall sensor with digital output. The type of sensor can be defined by mask option. The sensor must be located close to a cylindrical magnet. The number of pole pairs can be programmed.

### **Speed Setting**

The speed is selected by applying a voltage at pin SET. The voltage at this pin is fed into an ADC (referenced to VDD) and is converted to a 4 bit value. This value is the address of a ROM table in which the different speeds are programmed. This means that 16 different speeds can be selected.

The relation between voltage at input SET and the corresponding speed does not need to be linear. It can be freely chosen.

### **Soft Start**

A soft start procedure is activated at start up and is implemented to guarantee a smooth startup of the motor under all conditions. At very low speed the speed can not yet be measured and therefore several actions are taken so that the PI regulator can smoothly take over once the speed has increased sufficiently. The soft start function is configurable with the option mask.

Just after applying power to the electronics there is a delay time until the motor starts movement. The maximum allowable delay time is 300 ms.

### **Speed Set Ramping**

At any time when the speed setting is changed to a new speed, the change is internally generated with a ramp function to optimize the transient behavior of the PI regulator. This ramp function is configurable with the option mask.

### **Main Switch**

It is possible to program one or more speed settings with a zero speed. This will stop the motor. However for security reasons it might be considered to combine this setting with a switch to disconnect motor and/or electronics from the mains.

### **Overload shutoff feature**

625 ms after starting the motor (i.e. selecting a speed setting different from 0 rpm) the following function will be enabled: if the speed of the motor gets lower then a programmable value SLIM for longer then 320 ms, the motor speed is permanently set to 0 rpm. As a consequence the first possible timeout to recognize a blocked motor after start will be approximately 1 sec.

This state can only be left by disconnecting the power from the electronic circuit.

### **Overspeed shutoff feature**

If the speed of the motor gets higher than a programmable value SLIMA for longer then 320ms, the selected speed is permanently set to 0 rpm. This state can only be left by disconnecting the power from the electronics.

### MLX90804 Electrical Specifications

DC Operating Parameters  $T_A = 0^{\circ}\text{C}$  to  $85^{\circ}\text{C}$

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Ambient temperature	Tamb		0		85	$^{\circ}\text{C}$
Maximum chip temperature	Tch				150	$^{\circ}\text{C}$
Thermal resistance	Rth	PDIP8 package		110		$^{\circ}\text{C}/\text{W}$
Maximum allowed source supply current	IDD4m	Drivers off, all the current flows in the chip			10	mA

### Power supply

The 90804 supply pin (VDD1) must be connected by external series resistors and a rectifier diode to the AC line. An internal zener function limits the voltage at VDD1 to approximately 16V. For proper operation a decoupling capacitor must be connected between VDD1 and VSS.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Voltage applied at the supply pin	VDD1	IDD1 = 5mA	14	16	18	V
Internal 5V supply	VDD		4.6	5.0	5.4	V
Current consumption	IDD1	VDD1 = 14V		0.7		mA
For external circuitry	VEXT	IEXT = 8mA	4.5	5		V

### Power on Reset

This block ensures a correct start of the digital part. The reset signal (DPORB) goes up for  $VDD > V_{dporh}$  and down for  $VDD < V_{dporl}$ .

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
High level threshold	Vdporh			2.5		V
Low level threshold	Vdporl			2.0		V
Hysteresis	Vdphyst			0.5		V

### Analog Power-On Reset

This block tracks the voltage applied at VDD1. The triac firing is permitted if  $VDD1 > V_{aporh}$  and is stopped when  $VDD1 < V_{aporl}$ .

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
High level threshold	Vaporh			13		V
Low level threshold	Vaporl			10		V
Hysteresis	Vaphyst		2	3	4	V

### Zero crossing detector

This detector contains two comparators with hysteresis. The first comparator has reference at VDD1. The reference of the second one is VDD1-1V. Both outputs ZC1 and ZC2 are HIGH during positive half wave of the mains and LOW during negative half wave of the mains.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
High level threshold 1	Vzc1h	Referenced to VDD1		0.5		V
Low level threshold 1	Vzc1l	Referenced to VDD1		-0.5		V
High level threshold 2	Vzc2h	Referenced to VDD1		-1.5		V
Low level threshold 2	Vzc2l	Referenced to VDD1		-2.5		V

### Speed measurement

The chip has an input SPD to measure the motor speed. It is possible to connect a low cost inductor (between SPD and VSS) or a hall sensor with digital output. . The type of sensor can be defined by mask option. In case of the use of a coil the input levels are defined in the table below. In case of the use of a hall sensor, the levels are CMOS compatible.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
High comparator level	SPDHI			80		mV
Low comparator level	SPDLO			-80		mV

Note:

When used with a coil, the input voltage is on chip limited to approximately  $-280\text{mV}$ . However the current injected or pulled out of this pin should not increase above 1 mA.

When used with a hall sensor, the SPD input does not have an internal pull up resistor.

### Ignition driver

This driver operates as a current generator to fire the triac.

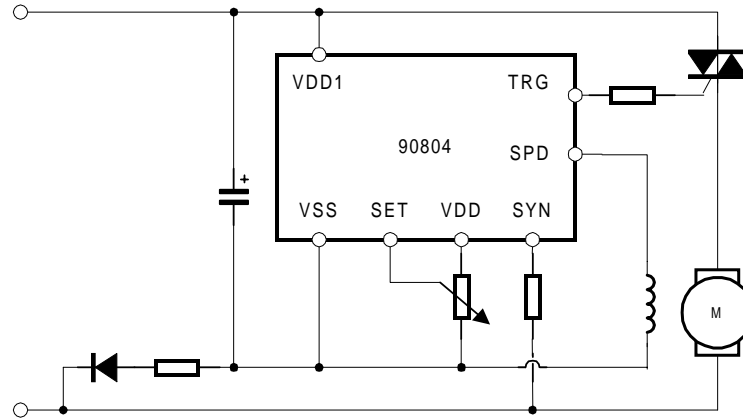
Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Triac gate current	ITRG	VDD1 > Vaporph	30	60	90	mA

### ADC

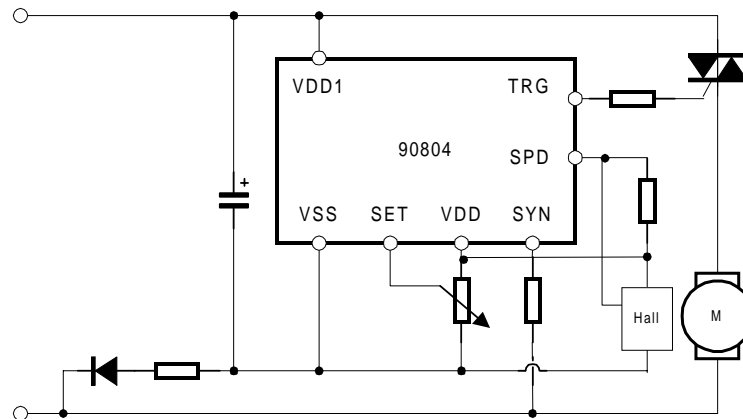
This is a 4-bit ADC.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Resolution				4		bits
Reference voltage	Vref			VDD		

**Application Example - coil sensor**



**Application Example - hall sensor**



### Digital features

#### Ignition detector

This block tracks if the triac is ON after each firing pulse. It senses the voltage at the gate of the triac. If the triac is OFF 10us after a firing pulse, a new pulse will be generated.

There is an option (active mask) allowing to eliminate the ignition detector circuit. Two firing pulses are generated every half period to fire the triac, instead.

#### Debounce of ADC

To assure a stable operation, the result from potentiometer reading is debounced before passing through.

#### Set of speeds (ROM table)

The analog voltage at pin SET is converted to a digital value. This digital value is addressing a value in the ROM table. This value defines the required speed and has a resolution of 10 bits.

The definition of the speed settings is totally free: it

SWITCH position	POT settings	SPEED [rpm]
1	0	1700
	1	1700
	2	1700
	3	1700
2	4	0
	5	0
3	6	2000
	7	2000
4	8	3500
	9	3500
5	10	7200
	11	7200
6	12	12200
	13	12200
	14	12200
	15	12200

does not need to be linear, nor continuously, and different ROM addresses can have the same speed.

An example can be found in the table: this is an application where the SET input voltage is defined with a rotating knob which has only 6 positions. Switch position 1 corresponds to a very low speed (1700 rpm) and covers position 0 to 3 of the AD converter. Switch position 2, corresponding to ADC position 4 and 5 has zero speed. For switch position 3 to 6 the speed setting is increasing.

#### Multiplier of input frequency from sensor

A frequency multiplier is designed in order to guarantee accurate measuring of the low frequency at the SPD input. The multiplier has measured the period of  $F_{spd} \Rightarrow N = T_{spd} \cdot F_m$ ;

where  $T_{spd} = 1/F_{spd}$ ;  
 $F_m = F_{osc}/MULT$ .

The value N determines the division coefficient of a down counter (divider), which clock input is  $F_{osc}$ . The output frequency from this counter has value  $F_{out} = F_{osc}/N = F_{osc}/(T_{spd} \cdot (F_{osc}/MULT)) = F_{spd} \cdot MULT$ . The output frequency is  $F_{spd}$  multiplied by coefficient MULT. The coefficient MULT is programmable from 1 to 256.

#### Frequency meter

The frequency meter is implemented as a simple counter. This counter is cleared at the beginning of every mains period (20ms). During the mains period the output frequency from the frequency multiplier ( $F_{out} = F_{ref} \cdot Mult$ ) is applied at the clock input of this counter. At the end of the mains period the value of the counter is stored in a latch. This stored value is proportional to  $F_{spd}$  and equals  $T_{mains} \cdot F_{spd} \cdot MULT$ .

The frequency can be measured during a full or during half a period of the mains.

If option  $FP = 1$  the frequency is measured over a full mains period.

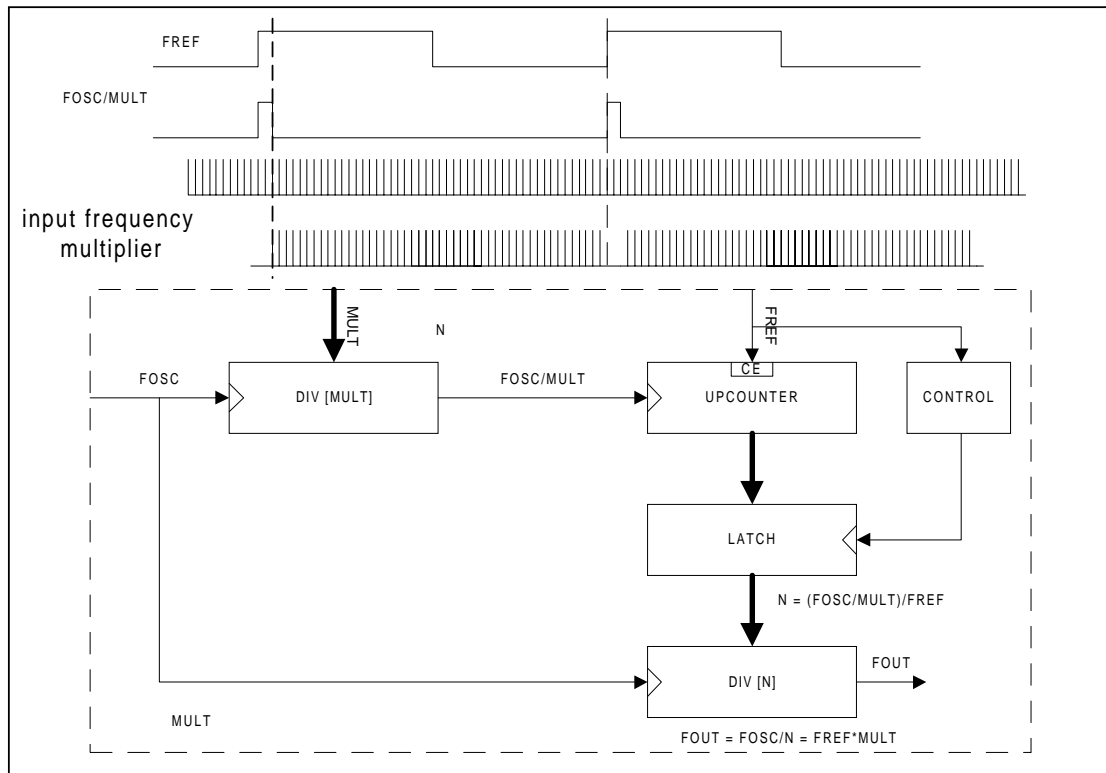
If option  $FP = 0$  the frequency is measured for a half mains period.

#### Soft start

The soft start is initiated after a proper power on reset sequence. The startup sequence can be influenced by several options.

The initial phase angle applied to the triac is defined as  $(MIN[9:0] - LD[9:0])$ , where  $MIN[9:0]$  is the minimum allowed firing angle, and  $LD[9:0]$  is the value initially stored in the integrator. The phase angle remains unchanged for a duration defined by the startup time  $SFT[1:0]$ .

After that time the PI regulator is enabled with a  $K_p$  factor defined by  $PX[3:1]$ . As long as the measured speed is smaller than the start speed (defined by  $SPE[1:0]$ ), the error signal at the input of the PI



PX3	PX2	PX1	Kp
0	0	0	8
0	0	1	4
0	1	0	2
0	1	1	1
1	0	0	1 -> 4
1	0	1	2 -> 4
1	1	0	1 -> 2
1	1	1	4 -> 8

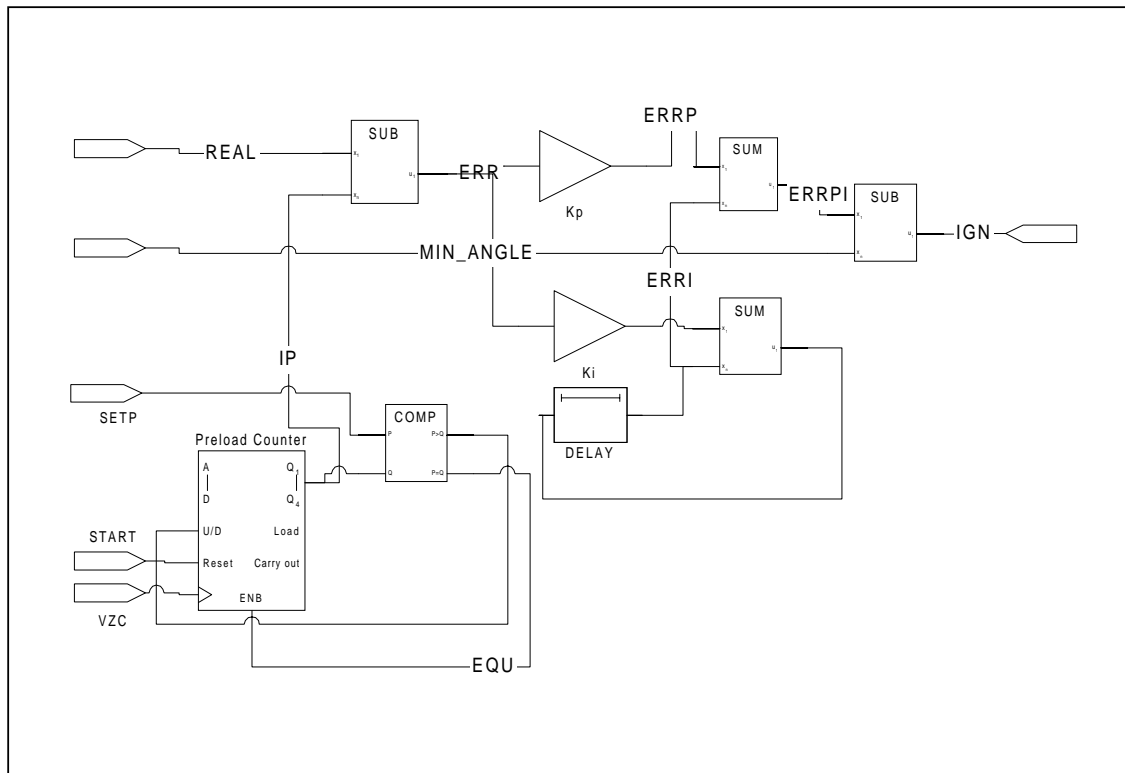
SFT1	SFT0	Duration in half periods
0	0	0
0	1	7
1	0	15
1	1	31

regulator is kept at zero. If  $PX[3] = 0$ , the  $K_p$  factor is fixed all the time. If  $PX[3] = 1$ , the  $K_p$  factor changes at the moment the measured speed gets higher than

the start speed, which is defined by  $SPE[1:0]$ . At the same moment the SETP integrator (see PI regulator) is enabled and preloaded with the value of the measured speed.

### PI regulator

The PI regulator calculates the ignition point that corresponds to a selected speed. The signal SETP is driven from the sets of speeds in the ROM table. The signal REAL is driven from the frequency meter and corresponds to the real speed. The error signal ERR at sample time  $n$  is the difference between the measured speed and the desired speed for this sample time. The error is multiplied by the proportional coefficient to form the proportional part ERRP. The same error is multiplied by the integral coefficient and summed with the previous errors. The accumulated integral error ERRI is then added to the proportional to form the final product ERRPI. This product is subtracted from the fixed MIN\_ANGLE to form the triac ignition point (the new estimated firing angle). The coefficients are mask programmable:  $K_p$  is defined by  $PX[3:1]$  and  $K_i$  is defined by  $SSE[1:0]$ . For smooth operation and to avoid overshoots, the setpoint (desired speed) is ramped from its present value to the a desired value:



SSE1	SSE2	Ki
0	0	1/ 8
0	1	1/ 16
1	0	1/ 32
1	1	1/ 64

### Speed Set Ramping

The SETP integrator is built around a 8 bit counter and guarantees a smooth transition when changing the speed setting. There is a comparator between SETP and IP. If SETP changes then the comparator enables the IP-counter until IP gets equal to SETP.

The clock, which defines the rate of change, can be defined for up and down counting independently, and equals  $F_{clkip} = 102.3KHz / (128 * (UPR[4:0] + 1))$  in case of counting up.

Since the value for the desired speed is 10 bit wide, and the counter only 8, the setpoint ramp speed from the table is effectively multiplied by 4.

### FLL

A frequency locked loop circuit is implemented to obtain a master frequency (approximately 100KHz) from a free running on-chip oscillator. Both FLL and frequency multiplier have the same functional blocks,

but the FLL uses the AC line frequency as his reference.

### Overload shutoff feature

625 ms after starting the motor (i.e. selecting a speed setting different from 0 rpm) the following function will be enabled: if the speed of the motor gets lower then a programmable value SLIM for longer then 320 ms, the motor speed is permanently set to 0 rpm. As a consequence the first possible timeout to recognize a blocked motor after start will be approximately 1 sec.

This state can only be left by disconnecting the power from the electronic circuit.

### Overspeed shutoff feature

If the speed of the motor gets higher then a programmable value SLIMA for longer than 320ms, the selected speed is permanently set to 0 rpm. This state can only be left by disconnecting the power from the electronics.

### Firing

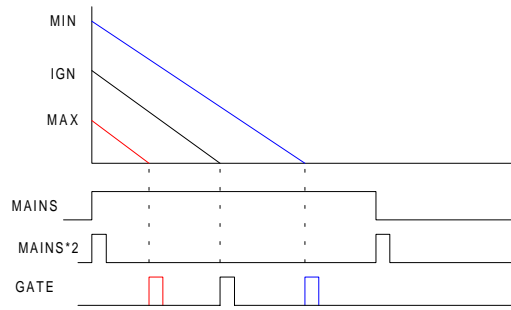
The PI regulator gives an ignition angle IGN. The resolution is 10 us. The firing circuit compares the ignition point with a maximum and minimum allowed angle MIN and MAX. MAX corresponds to



the maximum angle with the triac on (fired). This happens when the triac is fired with minimum delay from the zero cross. MIN corresponds to the minimum time the triac is fired. This happens when the triac is fired with maximum delay from the zero cross.

If the  $IGN < MAX$ , then  $IGN = MAX$ , thus firing with max angle. If  $MAX < IGN$ , then firing is done with  $IGN$  angle. The  $IGN$  value is compared with the value of a down counter, which is clocked by  $DCLK = 100kHz$  and is cleared at the beginning of every half period of the AC line. When this counter value gets equal to  $IGN$  a firing circuit produces an ignition pulse  $GATE$  with a duration selected with option  $DUTS[1:0]$ .

After each firing pulse the ignition detector is activated. This will check whether the triac is fired correctly and thus no additional firing pulses are required. If there is no current flowing in the triac additional pulses will be generated.



DUTS1	DUTS0	Duration in us
0	0	320
0	1	80
1	0	40
1	1	20

## Options

The following table lists all mask options of the 90804 chip:

Name	Description
MULT[7:0]	multiplication coefficient of $F_{spd}$
FPB	Gate of frequency meter
SFT[1:0]	startup time
PX[3:1]	Proportional coefficient $K_p$
SSE[1:0]	Integral coefficient $K_i$
SPE[1:0]	Start speed
LD[9:0]	Preload of Integrator
DWR[4:0]	SETP integrator down
UPR[4:0]	SETP integrator up
DUTS[1:0]	duration of firing pulse
MULT9	Enable retriggering
MIN[9:0]	min allowed firing angle
MAX[9:0]	max allowed firing angle
SLIM[9:0]	minimum speed limitation
SLIMA[4:0]	maximum speed limitation

## Pinout

Standard package is 8-pin dual inline package. (Known as DIP-8, PDIP-8, DIL-8 and PDIL-8)

Pin	Name	Type	Description
1	SET	Input	Speed setting input
2	SPD	Input	Speed measurement
3	TEST	Input	Test pin
4	SYN	Input	Zero cross input
5	TRG	Output	Triac driver output
6	VSS	Supply	Ground
7	VDD1	Supply	Supply, high level
8	VDD	Output	Reference voltage

## Applications Information

Following additional information is available for the MLX90804:

### **Application note: a basic phase angle speed controller**

This document describes in detail how to make an application with the MLX90804

### **The MLX90804 Demo Board**

This document describes the features and possibilities of the MLX90804 demoboard, and how it can be ordered.

### **Manual for definition of the options**

This document is a guide to the definition of all options and shows with an example how a set of options can be defined to fit your application.

### **MLXSPI programming users guide**

This is the users guide to the MLXSPI programmer, which can be used to program all options into the MLX90804 and MLX90805 kitparts. It describes both hardware and software of the MLXSPI programmer.

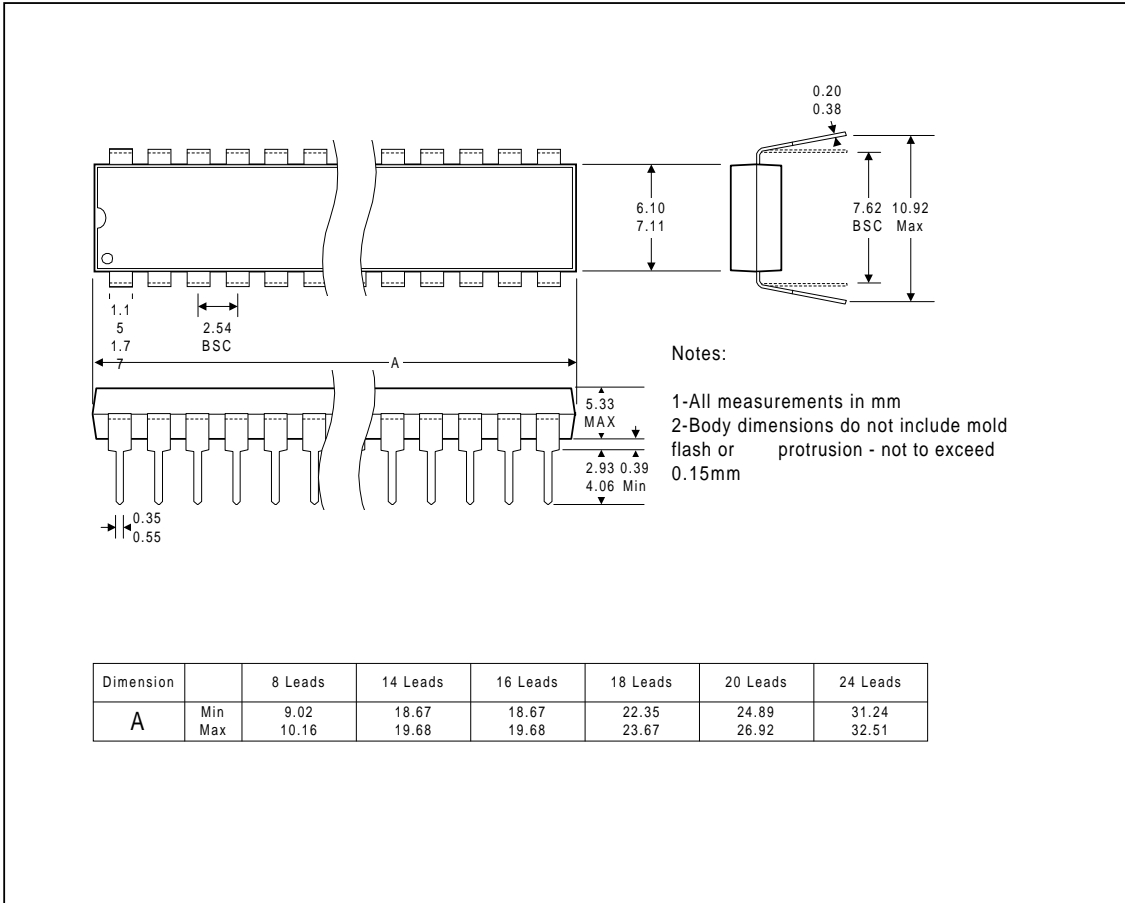
## ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

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**MLX90804 Physical Characteristics**



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