Application Note

Understanding MLX90614 on-chip digital signal filters

Scope

The MLX90614 is an easy-to integrate IR thermometer in TO39 package. It uses a two chip architecture to provide a fully integrated and calibrated solution. The sensor die is a CMOS MEMS thermopile and the signal is processed by a specially designed IC.

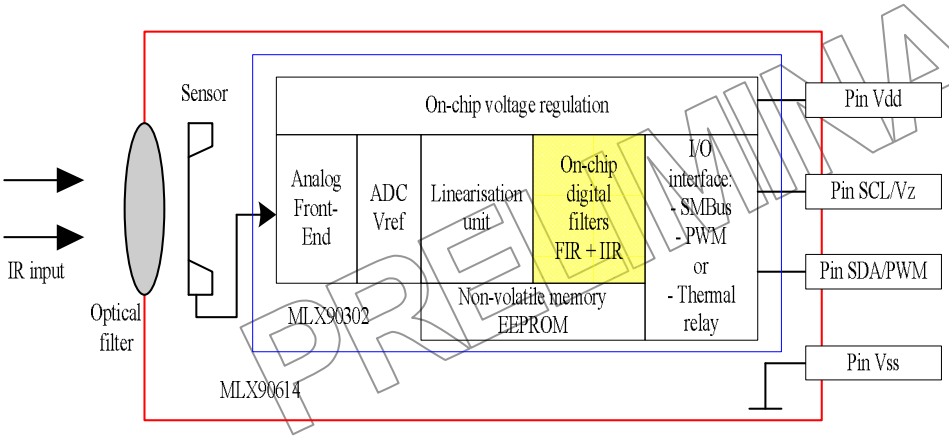

Fig. 1: Block diagram of MLX90614

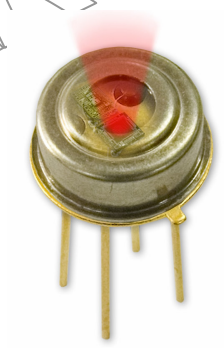

Fig. 2: MLX90614

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Current Application Note focuses on the on-chip signal filtering feature, implemented in digital part of that IC. This feature allows a trade-off between refresh rate (settling time) and noise reduction. On-chip filtering can also be used to dampen short pulse disturbances.
The settings for the filters are stored in the on-chip EEPROM and can be used in any of the three modes of operation: SMBus 2-wire interface, PWM output or thermal relay.

Applications

Thermometers customized for low noise are beneficial for increased accuracy measurements of slow processes, like:

- Healthcare;
- Livestock monitoring;
- Agriculture;
- Incubators.

Fast response thermometers are needed for other applications:

- Automotive blind angle detection;
- Industrial temperature control of moving parts;
- Temperature control in printers and copiers;
- Movement detection.

And the disturbance limitation is desired in systems that need to track the background temperature of an environment with unwanted thermal error sources:

- Mobile Air Conditioning control system;
- Commercial and industrial building air conditioning;
- Home appliances with temperature control;
- Thermal relay/alert.

Related Melexis Products

The EVB90614 is the Evaluation Board, supported by software (SW90614). These tools handle all the technical details for the user and make it simple to configure the MLX90614. The filters are supported by SW90614 as settling time (in milliseconds) and disturbance (spikes) permeability (in percent).

Filter configuration with the EVB/SW90614

The EVB/SW90614 provides a set of functions useful in configuring and evaluating the MLX90614 (for details check www.melexis.com). When the program is started, the SW90614 will check for MLX90614 devices, their version (3 or 5V devices, single or dual zone, etc.) and if they are inserted in the socket properly. Then the main menu of the SW90614 will appear,

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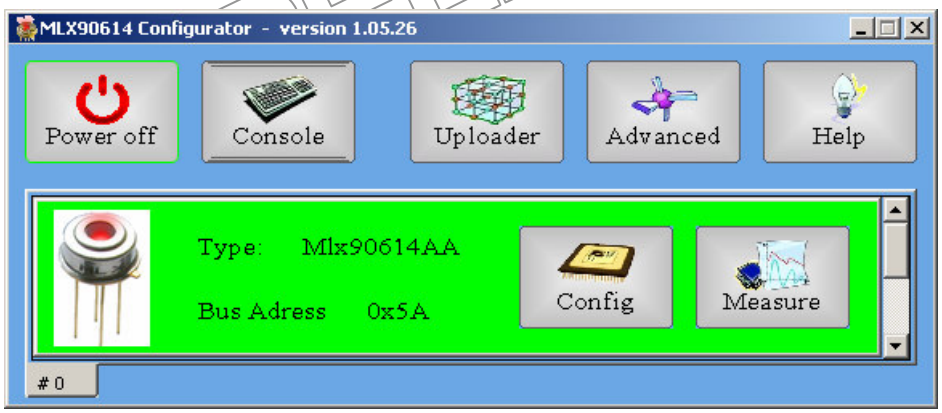

Fig. 3: SW90614 Main menu – 5V single zone MLX90614 is found

Configuration of the device is available through the “Config” button, calling the Configuration Utility,

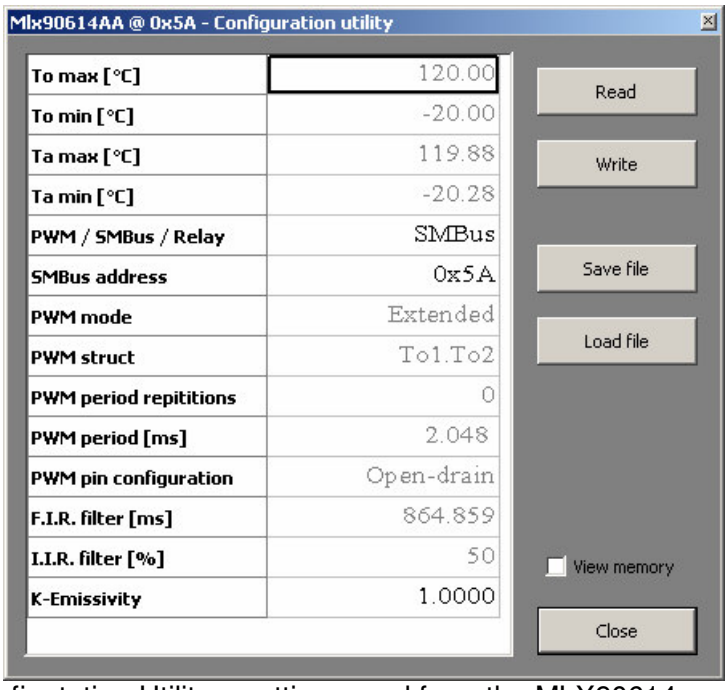

Fig. 4: Configutation Utility – settings read from the MLX90614 are displayed

At the bottom are the FIR and IIR filters' settings. They are available as drop-down menus. Note that, as the two filters act on the same signal path, the overall settling time depends on both the FIR and the IIR setting. The IIR filter setting has a straightforward effect on the step size allowed to pass to the MLX90614 output. That's why the **total** settling time is given in the FIR setting menu. Every time the IIR settings ar altered, new options for the FIR setting menu will appear. With the FIR set to 50%, the overall settling time, available in the FIR filter menu are 291.419 … 864.859 milliseconds. If we allow a 100% step to pass the signal processing path of the MLX90614, the settling time options are as shown in Fig. 5,

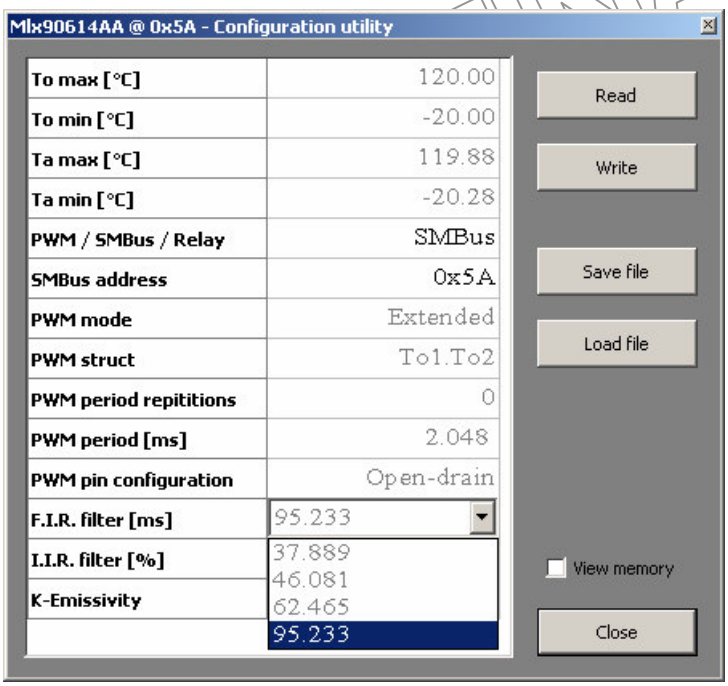

Fig. 5 Overall settling time options with 100% setting for IIR filter

- Note1: Factory defaults for the MLX90614 are chosen for minimum noise. That is 50% IIR filter setting and a maximum settling time (864.859 ms in the FIR filter options' menu).
- Note2: With a dual zone sensor the settling time will be higher as two sensors are processed instead of one.
- Note3: Having a new device read is the right moment to save the original device configuration. This allows us to return to the initial setting at any time afterwards. This is done by the "Save file" button, Fig. 6.

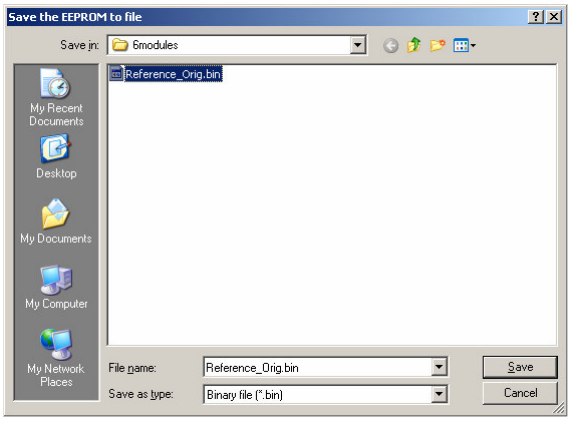

Fig. 6 Saving MLX90614 configuration.

All the available filters' settings are listed in the Appendix at the end of the document.

When the desired configuration is selected the "Write" button will program it in the EEPROM memory of the MLX90614.

The device can be also configured to operate in any of the 3 modes: SMBus,PWM, or thermal relay. The output temperatures available through any of these modes will pass the digital filters' settings programmed in the EEPROM after power-up.

For example, with the SW90614 we can configure the MLX90614 to output both object and ambient temperature in PWM mode (extended format PWM mode allows two temperatures to be transmitted in subsequent periods). Upon power-up, the MLX90614 will transmit the temperatures with both object (Tobj) and ambient (Tamb) temperatures' measurements processed for highest speed, like shown on Fig. 7.

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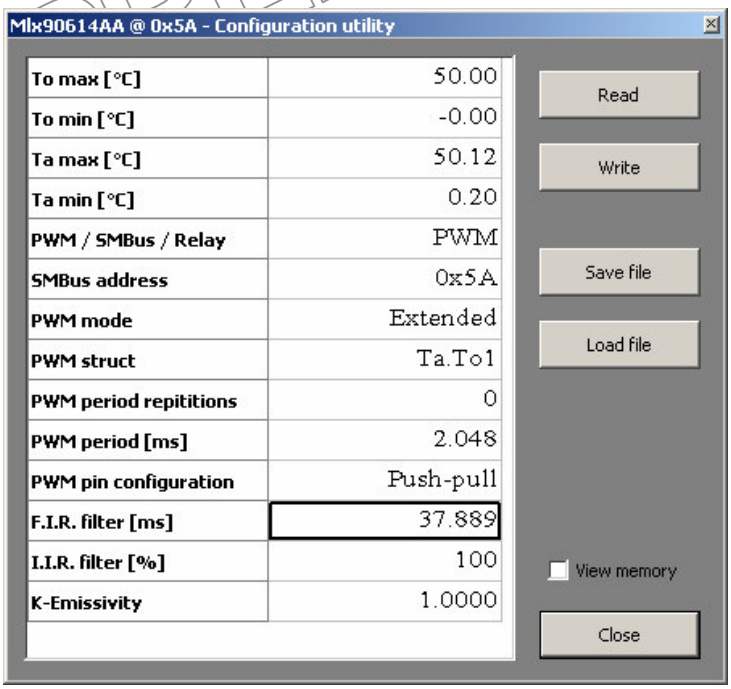

Fig. 7 MLX90614 configured for higher speed, filters set to minimum,
Extended PWM output Tamb,Tobj, period 2ms (500 Hz pulse train), push-pull output.
Temperature range set to 0..+50°C.

Why two filters?

The FIR (Finite Impulse Response) filter is provided primarily as a noise control. The IIR (Infinite Impulse Response) filter is useful to control the effect of fast temperature measurement changes. The settling time is a result of both filters working one after the other on the same signal path. Thus the overall settling time is dependent on both filters.

IIR option – limit the sharpness

The IIR filter can be used to "smooth" the measurements. Decreasing the signal step allowed to pass the signal processing path limits the magnitude of spikes. For example, if an object passes through the MLX90614 Field Of View (FOV), and measuring that object is not desired, the IIR filter can limit the disturbance. This is shown on Fig. 9.

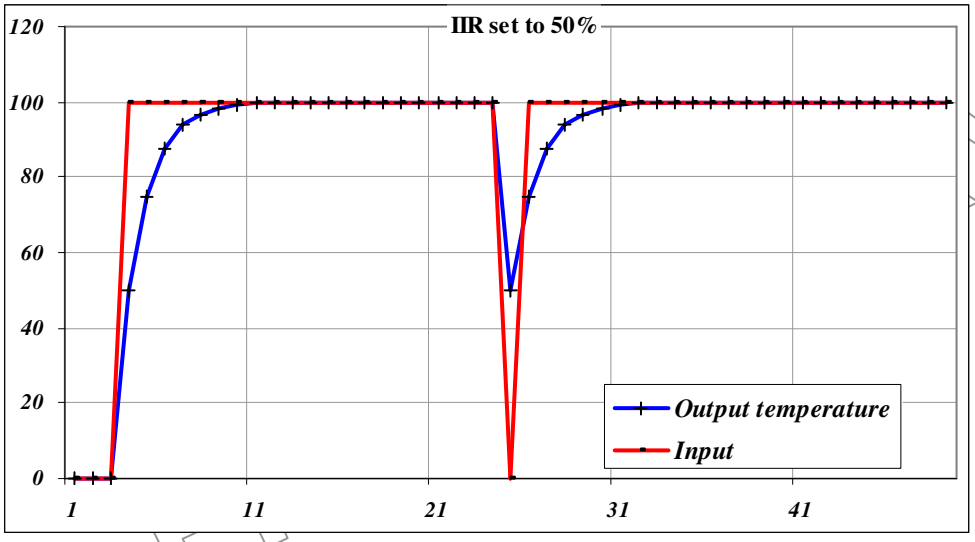

Fig. 9 IIR set to 50% response to step and spike

Settling time, defined as the time, after which a step will appear with new stable value at the output is dependent on both IIR and FIR filters. A single pulse however, will be limited to the percentage selected by the IIR configuration. On Fig. 9 this is the maximum limitation of 50%. The input temperature sensing element produces a spike, and the output stays within the 50% of that input spike magnitude.
In figure 10 the IIR response with 67% setting is shown. Settling time is reduced (therefore the measurement speed is increased), but at the output the spike is allowed to reach 67% of its initial magnitude at the input.
100% IIR setting results in no spike reduction, the output will follow the IIR input.
The percentages are directly applicable to temperatures, for example, a 5°C spike at 50% setting will reach 2.5°C at the output, 20°C at 50% results in a 10°C output, etc.

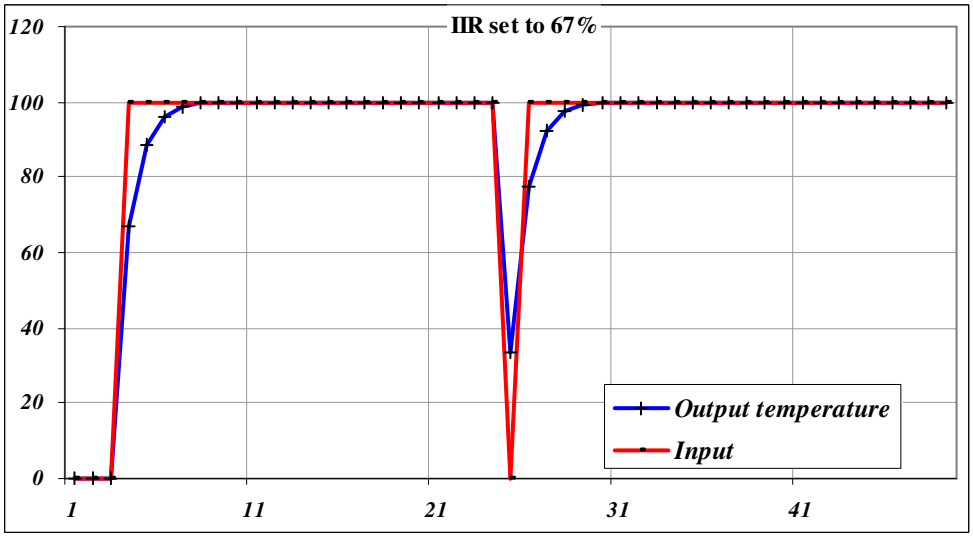

Fig. 10 IIR set to 67% response to step and spike

FIR+IIR: overall settling time

Both filters are controlled by EEPROM cell ConfigRegister1, at address 0x05. Note that when manipulating this cell without the SW90614 and the EVB90614 tools, care must be taken not to alter other bits in that cell as they contain factory calibration settings. The SW90614 ensures no calibration setting can be lost.

The IIR filter is controlled by bits 2..0. They provide the percentage settings already as given in Table 1. The "IIR Setting" column gives the IIR samples value one must use to calculate the settling time from EEPROM bits.
The FIR filter is controlled by bits 10..8. The "FIR Setting" column in Table 1 gives the FIR samples value used to calculate the settling time from EEPROM bits.
Note that the smallest values for the FIR setting are not recommended. If used they may degrade the performance of the MLX90614 to an unuseful level. The SW90614 does not provide access to any of them.

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Bits 10..8	FIR	FIR Setting	Bits 2..0	Max step	IIR Setting
000	8	1.34	000	0.5	10
001	16	1.6	001	0.5	10
010	32	2.12	010	0.5	10
011	64	3.136	011	0.5	10
100	128	5.184	100	1	1
101	256	9.28	101	0.8	4
110	512	17.472	110	0.666666	8
111	1024	33.856	111	0.57	9

Table 1 Filters' configuration bits in EEPROM ConfigRegister1

The settling time for the MLX90614 can be calculated from EEPROM using the following formula:

$$Tset = 9.719 + [\ IIR_{Setting} \times (\ FIR_{Setting} + 5.26)\ ] + [\ IIR_{Setting} \times (FIR_{Setting} + 12.542)\ ] + [\ Dual \times IIR_{Setting} \times (FIR_{Setting} + 12.542)\ ]\ ,\ (milliseconds)$$

"Dual" is the bit 6 in the same EEPROM register. It is used to identify dual zone MLX90614s (Dual = 1 for dual zone, MLX90614xBx). This bit is factory a setting and should not be altered.

Note: all mentioned times are typical and valid for the calibrated on-chip oscillator.

Conclusion

An in-depth understanding of digital filtering is not always easy and simple. The tools provided for the MLX90614 allow the user not to have to go in details. With the SW90614 the filters' settings can be configured in an easy manner.
Configurable in EEPROM, the filters options feature customization in a wide range of settling time. Measurement time, noise and impulse response can be managed for any output mode of the MLX90614.

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Appendix A

Settling time, ms	Min FIR (100b)	FIR 101b	FIR 110b	Max FIR (111b)
IIR 100%	37.889	46.081	62.465	95.233
IIR 80%	122.399	155.167	220.703	351.775
IIR 67%	235.079	300.615	431.687	693.831
IIR 57%	263.249	336.977	484.433	779.345
IIR 50%	291.419	373.339	537.179	846.859

Table 2 List of IIR and FIR filter options for **single zone** thermometers MLX90614x**A**x

Appendix B

Settling time, ms	Min FIR (100b)	FIR 101b	FIR 110b	Max FIR (111b)
IIR 100%	55.615	67.903	92.479	141.631
IIR 80%	193.303	242.455	340.759	537.367
IIR 67%	376.887	475.191	671.799	1065.015
IIR 57%	422.783	533.375	754.559	1196.927
IIR 50%	468.679	591.559	837.319	1328.839

Table 3 List of IIR and FIR filter options for **dual zone** thermometers MLX90614x**B**x