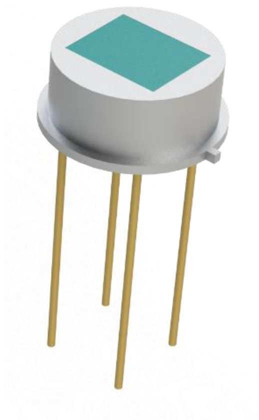
Application Notes

Digital TO39 QFCE Series Four Pin Operation



MAR 2022

TABLE OF CONTENTS

1 INTRODUCTION

KEMET's original digital flame sensors employ a surface mount footprint with 8 pins, providing additional signals which allows greater flexibility for the design engineer.

This application note covers the required hardware and operational requirements of the KEMET QFCE sensor when only 4 pins are used (compared to the QFS and QFSM series).

Operational differences arise from the reduction of pins available on the TO-39 package. Therefore, the method of operation is required to change to facilitate correct operation. This document covers some options for the additional surrounding circuitry and should be used in conjunction with the corresponding document *Application Notes – Digital TO39 QFCE Series TO Software* for the software differences and with the document *SMD Sensor Reference Manual*.

The digital range of thin film pyroelectric IR sensors combines high performance with a high level of configurable electronic integration in the smallest SMD package or in a TO39 package.

KEMET's QFCE pyroelectric flame sensors combine high sensitivity with fast response times and high dynamic range to ensure rapid and accurate detection of small and large flames, nearby or over larger distances.

These high-sensitivity flame detectors integrate digital front-end circuitry to provide all of the associated analog electronics required for sensing flame events. These events can then be interpolated by direct connection to a microcontroller. All of this occurs in an industry standard TO39 package.

The thin film PZT substrate allows industry leading response times providing high responsivity over the full frequency of flame flicker from 3 to 30 Hz. The industry standard I^{2}C communication interface not only provides plug-and-play connectivity to microcontrollers, but also allows easy tuning and calibration via programmable gain and filtering, offering maximum flexibility at system design level.

2 SENSOR CONNECTIONS

Pin	Function	Direction
1	SDA	In / Out
2	V_{Supply}	In
3	SCL	In
4	GND	In

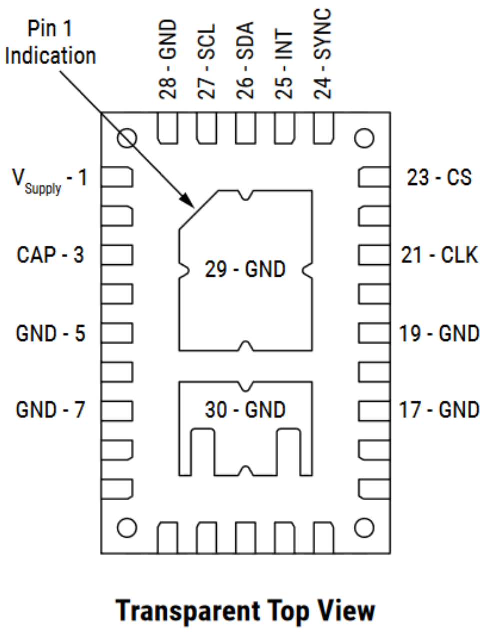


Figure 1 – Digital SMD Sensor

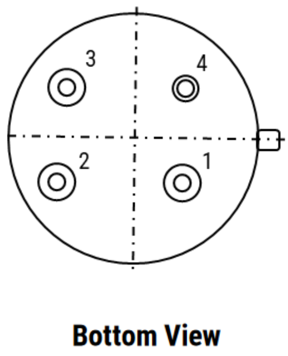


Figure 2 – Digital TO Sensor

The above figures show the connections available for KEMET's SMD or TO digital sensors. Functionally the digital TO is equivalent to the SMD version used with only 4 pin connections. The TO package only allows for V+, GND and the I^{2}C lines. This means that the following pins that can be used in the SMD version of the sensor are not accessible.

1. INT
2. SYNC
3. CLK
4. CS

The following sections describe the use of these pins and the impact of the restricted number of pins on the reduction in functionality.

2.1 INT

The INT pin on the SMD sensor indicates to the attached MCU that there is data available in the FIFO and ready to be read out using the appropriate I^{2}C command. The lack of access to the INT pin means that the FIFO must be checked using the FIFO status command.

The FIFO status packet, as described in Section 13.3.3 FIFO Status Packet of the *SMD Sensor Reference Manual*, and contains the interrupt pins status in bit 0 of the returned byte and so can be used to poll the FIFO status. Also, this implies that any Sleep/Wake-up function needs to be done by polling.

Figure 3 shows the logic analyzer results from during normal operation of a SMD sensor that has access to all the pins.

Figure 3 – Interrupt Pin Operation Mode

The interrupt pins all go low at the same time due to the daisy chaining of the devices with the sync signal from the master making all sensors take a sample. As data is read out from each device and then the FIFO cleared the INT lines go low one at a time. The I²C commands to read the data out begin once the MCU has detected the INT line states.

Figure 4 shows the FIFO status being checked to determine data availability.

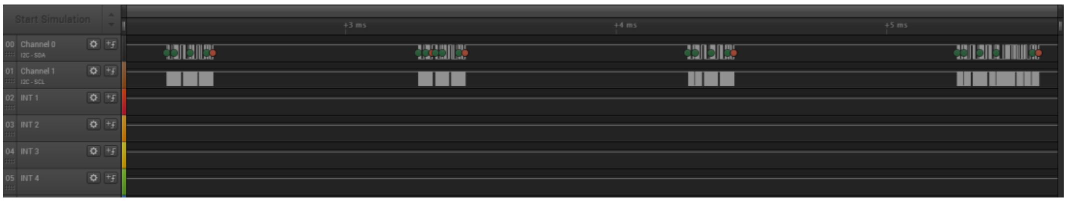


Figure 4 – FIFO Status Polling Operation

The above figure shows three FIFO status checks that return a FIFO status corresponding to no data and then a final FIFO status check that indicates there is data available followed by reading the data out and clearing each FIFO in turn.

2.2 SYNC and CLK

These pins on the SMD sensor give the synchronization of sampling between multiple sensors. Under 4 pin operation each sensor uses its own internal CLK and SYNC signals so every digital TO sensor must be set up as a master by configuring the AFE register as described in the *SMD Sensor Reference Manual*, in Section 13.3.5 Analog Front End Packet.

This has the effect of removing the ability to daisy chain the sensors, they are independently clocked devices.

2.3 CS

The chip select pin is also not available in 4 pin connected sensors. On the digital TO sensor, the CS is wired internally directly to the positive voltage input. Thus, when the voltage supply is turned on, the CS signal goes high.

This does mean that if multiple sensors are being powered from the same supply, there needs to be a way to re-address the devices separated by powering them on in sequence. This is discussed in the Section 3.2 of this document.

3 SOLUTIONS

The limited number of pins on the digital TO package means that a subset of the functionality of the SMD sensor is accessible.

The solutions are grouped into two sections, **initialization** and **operation**.

3.1 Initialization – Turning the Sensors On and Off

On the KEMET digital TO flame sensing evaluation kit USEQFCK9000000, the digital output from the MCU controls a separate power switch for each of the sensors connected to the MCU. If any individual flame sensor requires to be reset, then these power switches facilitate control over individual sensors.

If the MCU is reset then all flame sensors should be reset at the same time. The sensor power switch should ensure that the VDD pin is pulled to ground rather than left floating. A floating supply does not allow correct reset timings to occur within the sensor and therefore can have adverse effects if not controlled correctly.

The power switch schematic is shown in Figure 7. There are connections to this in both Figures 6 and 8.

In addition to the control of the power for each sensor the I²C CLOCK pin must also be controlled, this is a requirement brought about by the lack of Chip Select (CS) signal on the digital TO-39 package.

If multiple sensors are to be used on the same communication bus, then each device will be required to be reprogrammed to have a unique I^2C address. This is performed by controlling each I^2C clock line to individual sensors. The control over the clock line also prevents the devices from being powered from the I^2C bus when the power to the sensors is being reset.

3.2 Initialization – Independently Addressing Devices

On our QFS and QFSM series of SMD devices the sensors are initialized by setting the CS of one device at a time and re-addressing each device until all sensors have distinct addresses on the I^2C bus.

The operation of the digital TO-39 devices is different as there is a single power switch for all sensors. The solution is to use a chip that can allow or deny access to the I^2C clock signal to each sensor. This means that although the data is getting to all sensors the I^2C hardware is not being clocked, so the incoming data is not being read.

With this additional piece of hardware, the same code for the digital demo board can be used since the same signals used to activate chip select are used to control sensors receiving the I^2C clock.

If multiple sensors are to be used on the same I^2C bus, then each device requires to have a unique I^2C address, this is achieved by performing the following sequence.

Ensure the sensors have been correctly reset, then using control over the I^2C clock lines disable all devices that you are **not** trying to reprogram the associated I^2C address for.

Reprogram the I^2C address according to the *SMD Sensor Reference Manual* and your required address, once completed leave that device powered on and now re-enable the I^2C clock line to the next device in the chain that you intend to program. Follow this procedure for each and every device on the I^2C bus, ensuring each device in the chain has a unique address.

KEMET sensors do not contain Flash memory, so every time the power to the sensors is disrupted, you should ensure that you reset and reprogram each individual I^2C address. Failure to reset or reprogram the devices will result in random failures when reading or writing data to each of the sensors.

3.3 Operation Checking for Data

With the digital SMD sensors there are various methods for the MCU determining whether there is data in the FIFO.

1. Use INT pin of the sensor and Interrupt within the MCU.
2. Use INT pin of the sensor and Poll it with the MCU.
3. Use the I^2C FIFO_Status command and check the bit corresponding to the INT status. This is effectively polling the FIFO_Status.

Since the first two require the INT pin of the sensor, they cannot be used in 4 pin operation, the only method of checking whether there is data in the FIFO, is to use the I^2C FIFO_Status command.

It is worth reminding here that when polling the FIFO_Status, the I^2C bus is being used. Therefore, to improve power usage the frequency of checking the FIFO_Status should be kept to a minimum.

As an example, in the digital TO evaluation kit this has been accomplished through an interrupt that uses the current sampling rate and power mode to determine its frequency of checks.

The lack of synchronized sensor sampling produces the following result in the FIFO polling data read out mode. The narrowest I^2C packets correspond to none of the sensors having data in the FIFO. The widest packets correspond to all sensors having data in the FIFO. The other I^2C packets correspond to FIFO status checks that have returned only a subset of sensors with data available.

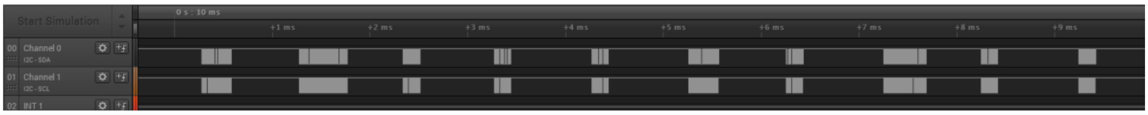


Figure 5 – FIFO Polling – Effect of Unsynchronized Sampling

Since the sensors are independently clocked, the point at which data is available for each sensor is different. Care must be taken when designing the firmware to read the sensors in order to avoid losing data.

3.4 Demo Board Circuit Schematics

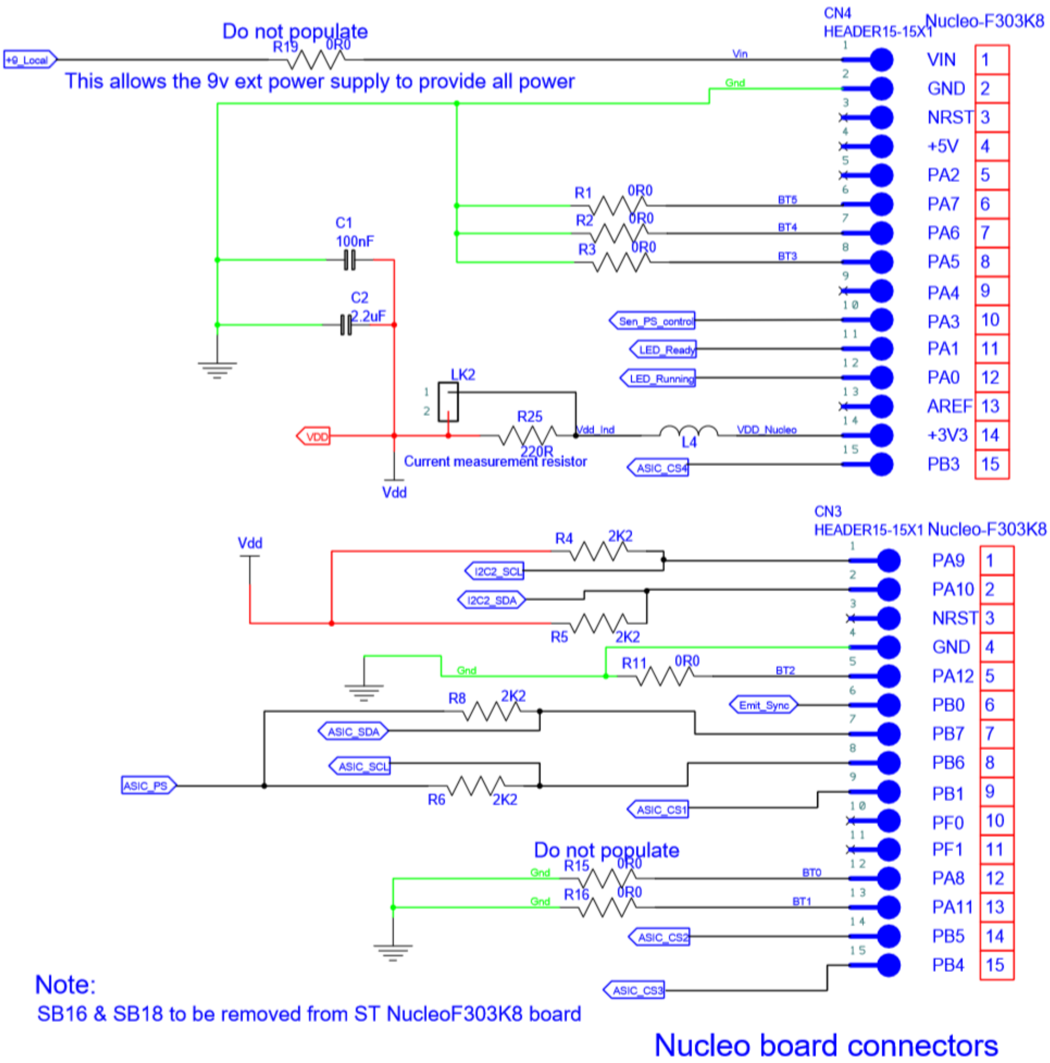


Figure 6 – MCU Connections

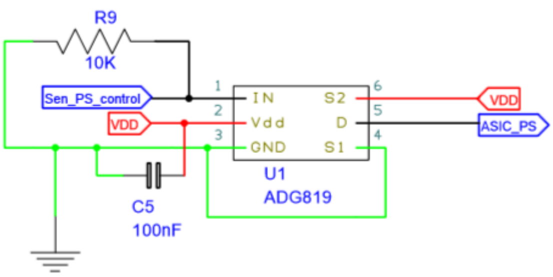


Figure 7 – Power Supply Switch

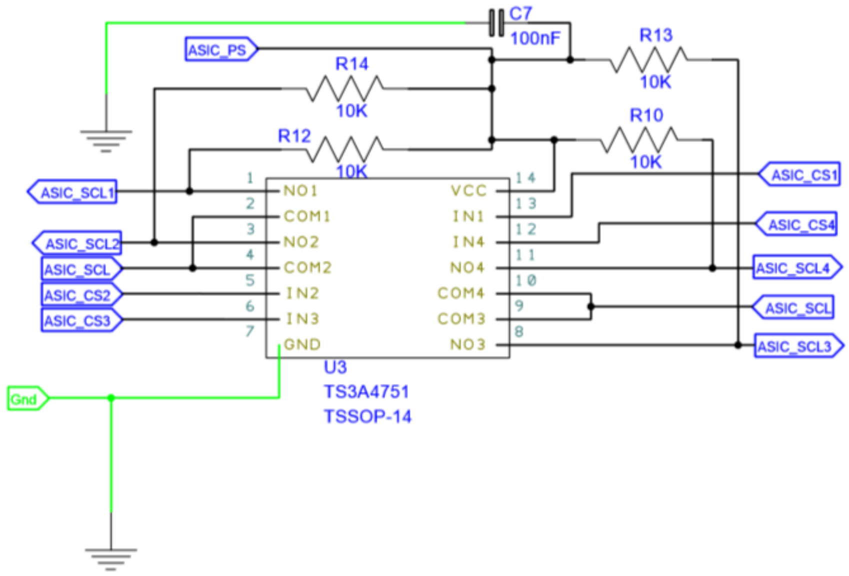


Figure 8 – Sensors Clock Switches

3.4.1 Notes on the Evaluation Kit Schematics

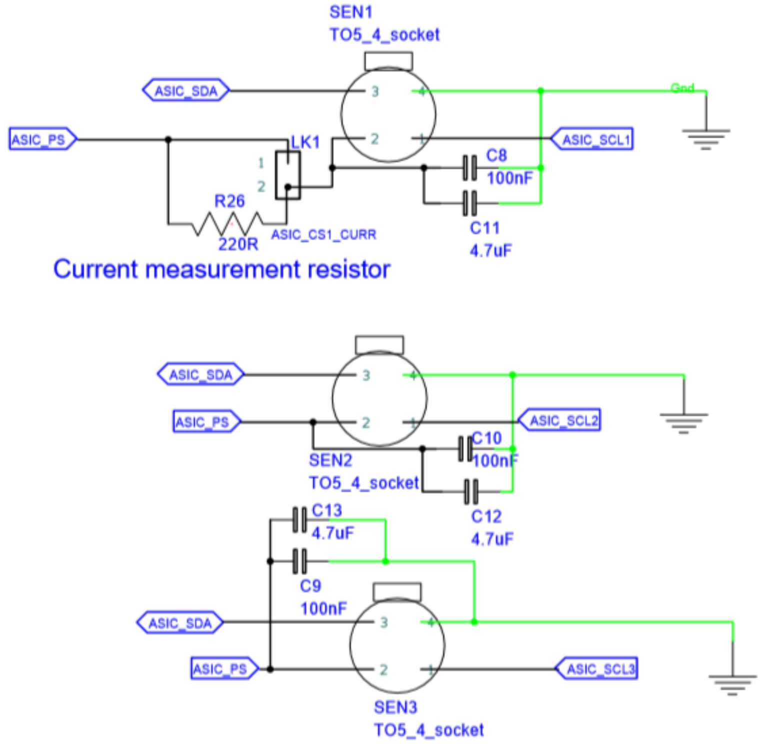


Figure 9 – Digital Sensor Sockets

Developers should note that the I[2]C pull-ups and the I[2]C clock switch receive their 3.3 V from the output of the power supply switch (controlled via the MCU).

The reason for this is that when the digital sensor does not have a 3.3 V applied to its V_{Supply} pin then the other digital IO pins can feed onto the 3.3 V rail of the sensor's ASIC through internal protection diodes. However, if there is no 3.3 V supply then any voltage over 0.6 - 0.7 V on the other pins is fed onto the 3.3 V rail and hence the device could be powered through the I[2]C lines. To avoid this, they are kept low until the 3.3 V signal is supplied.

4 CIRCUIT FOR LOW POWER APPLICATIONS

The above descriptions are for the current version of the KEMET demo board. This was chosen to reduce the component cost. However, it does mean that the lowest current consumption for sleep mode is not achievable.

In low power applications, the individual control over power and clocks to each sensor will drastically reduce the power consumption of the final application.

Considering the digital TO flame sensing evaluation kit's expected usage as an example for the differences in power consumption performance for a different circuit choice, the kit should only be actively analyzing the data if the flame sensor is above some threshold value. This implies that the sensors can be asleep and can make use of the wake-up parameters described in the Section 13.3.7 of the *SMD Sensor Reference Manual*. If you are unfamiliar with the WUP packet, it is recommended to use the *Flame Sensing Evaluation Tool (Digital)* software as it contains a useful visualization aid to setting up and testing the parameters. This Evaluation Tool software is available to download from our Environmental Sensors page or on https://brandfolder.com/s/prjtc4mp6xmwjrhr8kphjwr.

4.1 TO Flame Sensing Evaluation Kit (Digital) – USEQFCK9000000

As mentioned above the Flame Sensing Evaluation Kit should ideally be asleep most of the time unless an event considered to be a fire is detected on the sensor output. This means that if the signal level is just noise, then the devices should remain asleep. The level of signal required for a wake-up condition is determined by the WUP packet. If all three devices are asleep on the digital TO Flame Sensing Evaluation Kit, then the minimum current consumption of the sensor system sits at around 18.2 µA. However, since as the interest is only in the flame sensors signal to determine a wake-up event, the other two devices could be powered down. This would put the sleep state current consumption at 7.3 µA.

The downside to the above reduction to lowest current consumption is the additional hardware cost. As is mentioned in Section 3.4.1 of this document, the I^2C cannot be connected to a powered down device, otherwise the 3.3 V feeds onto the Vcc rail of the sensor through protection diodes. Therefore, if each device can have power independently, it also needs to have the I^2C lines connected only when it has power. This will avoid any problems with registers not initializing properly in the ASIC. This implies that there should then be a single power and two I^2C signal switches per sensor.

Circuit Type	Power Switches in Circuit	I^2C Switches in Circuit	Sleep Mode Sensor Circuit Current
Low Cost	1	1	18.2 µA
Low Current	3	2	7.3 µA

Table 1 – Component Cost and Corresponding Current Consumption

Here are two examples of possible solutions:

Analog Devices: ADG819BRTZ-500RL7

And

Texas Instruments: TS3A4751PWR.