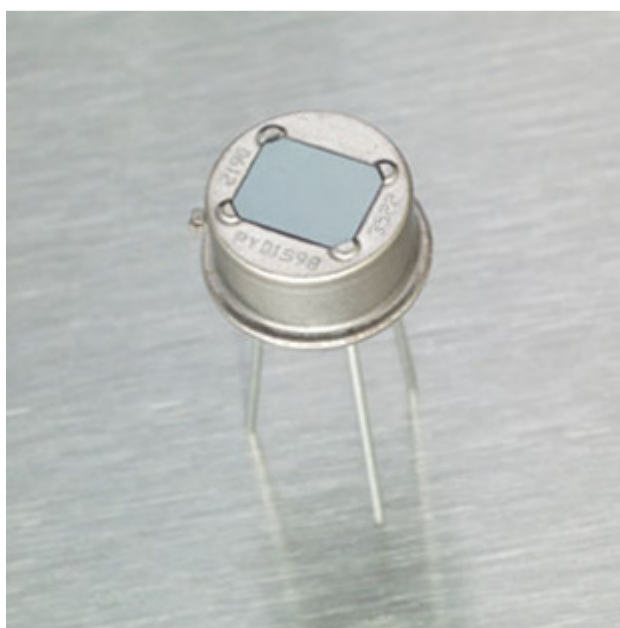


New LowPower DigiPyro® (2nd Gen.) Application Note (prelim.)

Product Description, Features, Advantages and Applications

Version 0.3 - Date: 27.04.2016



Introduction

Motion detection applications typically use pyroelectric infrared detectors as sensing unit. Excelitas innovation has successfully launched digital Pyroelectric Detectors to the market. The newest member of this DigiPyro® family is the LowPower DigiPyro® 2nd Gen.

Features and Benefits

- Supply Voltage 1.8V
- Low Supply Current
- Wake-up host microcontroller from Sleep Mode
- Programmable Detection Criteria
- Programmable Filter Characteristic
- Digital output "Direct Link"
- Digital input "Serial In"
- 4-pin TO housing
- Low EMI susceptibility

Applications

- Wireless Intruder Alarm
- Battery operated Devices
- Low Power Motion and Presence Detection
- Door Openers
- Low Power Monitoring / Control Devices

1 General

The LowPower DigiPyro® 2nd Gen. offers reduced power consumption compared to standard DigiPyro®. In addition it can be individually configured for wake up function of a complete Motion Detector, allowing further reduced current consumption of the complete Motion Detection unit.

The detector comprises of the pyroelectric elements, the analog to digital converter and the digital signal processor, all built in a TO5 can. The configuration for the power saving Wake Up Mode as well as other operation modes of this specific detector series will be described below.

The sensor is ideally suited for battery operated wireless motion sensors that make use of a host microcontroller to care for the communication in both directions towards the LowPower DigiPyro® 2nd Gen. as well as towards peripheral installations. The important new feature is continuous motion sensing, signal processing and event / motion detection, solely handled by the LowPower DigiPyro® 2nd Gen. while the host microcontroller can be set into a power saving (Sleep-) mode. Only upon the detection of an event or motion per its programmed configuration, the LowPower DigiPyro® 2nd Gen. signals the microcontroller to wake up. As the hosting microcontroller typically requires much higher supply current than the LowPower DigiPyro® 2nd Gen. (I_{dd} = approx. 3 μ A) the sleep mode offers advantageous power saving. Hence, the overall power consumption of the entire system is significantly reduced by setting the microcontroller to a Sleep-mode.

Detected motion is signaled through the push-pull output (Direct Link **D/L**) of the LowPower DigiPyro® 2nd Gen. Motion signaling operational modes and parameters are programmable on the device. The parameters for threshold, timing and functional options are all configurable by a digital pin called Serial-In (**SERIN**).

2 Data Communication

2.1 Serial-In configuration interface

The new digital interface called “**SERIN**” allows the setting of operation modes by writing parameters to an internal Configuration Register, see table below.

2.1.1 Serial Data Input

The configuration of the pyro mode is done by host microcontroller by use of the detector input pin referenced to as SERIN. The host microcontroller has to generate a **Low to High** transition on SERIN and subsequently apply the data bit value (0/1).

The ‘low’ and ‘high’ time (t_{SL} , t_{SH}) for the transition can be very short (1 instruction cycle of the microcontroller). The data bit value must be applied for at least 2 system clocks (t_{SHD}) of the Low Power DigiPyro® 2nd Gen. Whenever the device has received more than 25 data bits and the transfer of data bits is interrupted for a period greater than 16 system clocks ($t_{SLT} > 550\mu s$), the last data received is latched into the configuration register. The transmission of a 25 bit data should not be interrupted for more than 15 system clocks ($> 515\mu s$), as the device may latch the data already at this stage.

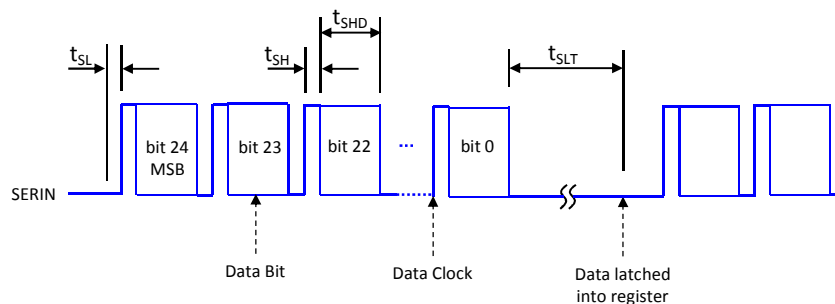


Figure 1 Serial Data Clock-In Sequence

```

#define PIN_IS_INP      0
#define PIN_IS_OUTP     1

#define SERIAL_IN       PORTD.3    // Port Pin for LowPower DigiPyro SERIN
#define DSERIAL_IN      DDRD.3     // Port Pin Direction Register

void writeregval(unsigned long regval){

int i;
unsigned char nextbit;
unsigned long regmask = 0x1000000;

    DSERIAL_IN = PORT_IS_OUTP;
    SERIAL_IN = 0;

    for(i=0;i < 25;i++){
        nextbit = (regval&regmask)!=0;
        regmask >>= 1;
        SERIAL_IN = 0;
        SERIAL_IN = 1;
        SERIAL_IN = nextbit;
        delay_us(100);
    }

    SERIAL_IN = 0;
    delay_us(600);
}

```

Figure 2 Example: C Code for a host microcontroller to implement the Serial Data Clock-In Sequence

Above function **writeregval()** writes 25 bit into the configuration register of the LowPower DigiPyro® 2nd Gen. with the pin SERIN connected to the microcontroller's port pin **D.3** for example.

Bit[31:25] of the 4-Byte wide parameter **regval** are unused and Bit[24:0] are written to the configuration register in such way that the resulting bit order of the configuration register value is the same order as held in **regval**.

2.1.2 Configuration Register

The detector can be set into multiple operation variants, including band pass, pulse count and sleep mode. This is established by setting configuration registers as per following table:

Bit-No	Register	Name	Remarks
[24:17]	[7:0]	Threshold	The value defines the positive and negative threshold for detection. The ADC values after the BPF are compared to the threshold for counting the pulses. Threshold = [RegisterValue]
[16:13]	[3:0]	Blind Time	No motion detection for the time programmed (0.5s .. 8s), after the interrupt output changed from “H” to “L” Ignores motion after the interrupt output is switched back to Low Range: 0.5s .. 8s. The blind time = [RegisterValue] * 0.5s + 0.5s
[12:11]	[1:0]	Pulse Counter	Amount of pulses during the specified window time which triggers an alarm event (interrupt = “High”) 1 .. 4 pulses with/without sign change in between Amount of pulses = [RegisterValue] + 1
[10:9]	[1:0]	Window Time	The specified time window (2s .. 8s) in which the amount of pulses will trigger an alarm event (interrupt = “High”) For noisy environments 2s .. 8s window Window time = [RegisterValue] * 2s + 2s
[8:7]	[1:0]	Operation Modes	0 = Forced Read Out Mode 1 = Interrupt Read Out Mode 2 = Wake Up Operation Mode 3 = reserved
[6:5]	[1:0]	Filter Source	Following source voltages are selectable: 0 = PIR (BPF) 1 = PIR (LPF) 2 = reserved 3 = Temperature Sensor For Wake Up Operation Mode ‘0’ or ‘1’ has to be selected.
[4:3]	[1:0]	Factory Params.	Must be set to 0x2 (10 binary)
[2]	[0]	High Pass Filter Freq.	0 = 0.4 Hz 1 = 0.2 Hz
[1]	[0]	Factory Params.	Must be set to 0x0 (0 binary)
[0]	[0]	Pulse Detection Mode	0 = signal has to exceed the threshold and change of sign 1 = signal has to exceed the threshold without change of sign

Operation Modes

The detector can be operated in different modes as per above table. The mode can be changed by the host microcontroller at any time.

For example it is possible first to set the criteria for motion detection on the detector itself and to put the detector into the Wake Up Operation Mode. Whenever the criteria are met, the host microcontroller wakes up and puts the detector for example into the Forced Read Out mode in order to quickly read data from the detector and to perform further processing.

a) Forced Read Out Mode

This mode can be used for continuous data read out with time intervals that are defined by the host microcontroller. This mode is in principle identic to the standard DigiPyro® read out mode and is described in chapter 2.2.2 *Description of the Read Out Sequence* mentioned below.

b) Interrupt Read Out Mode

This mode can also be used for continuous data read but the time intervals for data read out are fixed and defined by the Low Power DigiPyro® 2nd Gen. The LowPower DigiPyro® 2nd Gen. creates a LOW to HIGH transition typically 16ms after the last data read out.

This signal can be used to trigger an external interrupt of the host microcontroller to initiate the execution of the read out procedure. In this case, the D/L is already in a high state and so it is not required to generate the 110 – 150 µs pulse (t_{DS}) prior to reading the bit states as needed in the Forced Read Out Mode above.

Restrictions / Limitation:

- The readout shall start within 50µs after the LowPower DigiPyro® 2nd Gen. has generated the Low to High transition.
- Due to the tolerances of the internal clock frequency (see Product Specification) a variation in the timing for the interrupt signal can be recognized.

c) Wake Up Operation Mode

This mode is the new feature of the Low Power DigiPyro®. In **Wake Up Operation** mode the Pyro's detection unit continuously monitors the PIR signal while the host microcontroller may be inactive (Sleep Mode). Once the configured criteria (see below) for motion are met the LowPower DigiPyro® generates a Low to High transition on the D/L output. This Interrupt signal can be used to wake up the microcontroller in order to process the detected condition.

This can be any immediate action (trigger an alarm for example) or further data readout via D/L in order switch between different cases of actions in the host controller. If it is needed to further read out data once the Wake Up interrupt triggered and D/L is already HIGH, it is not required to execute the SetUp pulse. It is only needed to leave D/L HIGH for least 50µs before executing the LOW to HIGH transition that initiates the output of the MSB. The output register is not updated as long as D/L is HIGH.

Settings for Pulse Counter, Pulse Detection Mode, Window- and Blind Time

A pulse is generated after the signal level exceeds the sensitivity threshold for the first time. When Pulse Detection Mode is set to 0, subsequent pulses are counted whenever the signals changes sign **and** exceeds the threshold again. When Pulse Detection Mode is set to 1, subsequent pulses are counted whenever the signal exceeds the threshold again. The interrupt is signalized when the number of pulses that are set in the configuration register occurred during the window time. The blind time starts when the host microcontroller pulls the interrupt to LOW. Pulse counting is inactive during the configured blind time.

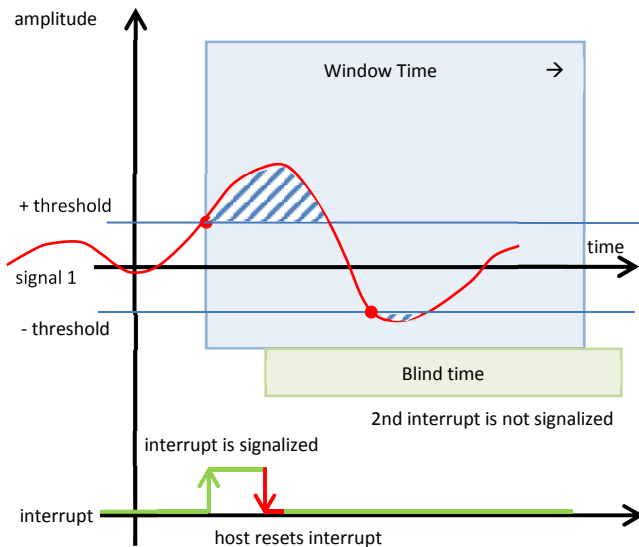


Figure 3 Signal Example for Pulse count = 1, Register Value[12:11] = 00b = 0 dec. and Pulse Detection Mode = 0, Register Value [0] = 0.

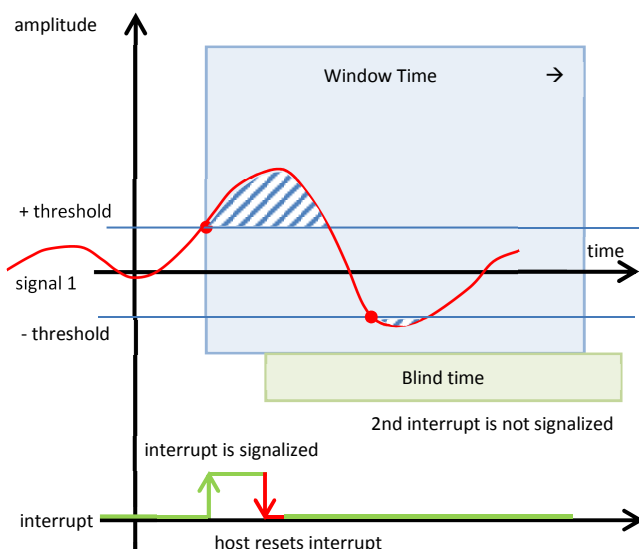


Figure 4 Signal Example for Pulse count = 1, Register Value[12:11] = 00b = 0 dec. and Pulse Detection Mode = 1, Register Value [0] = 1.

When the Pulse Counter is set to trigger on the first pulse (Register Value [12:11] = 0), there will be no difference whether the Pulse Detection Mode is set to 0 or 1.

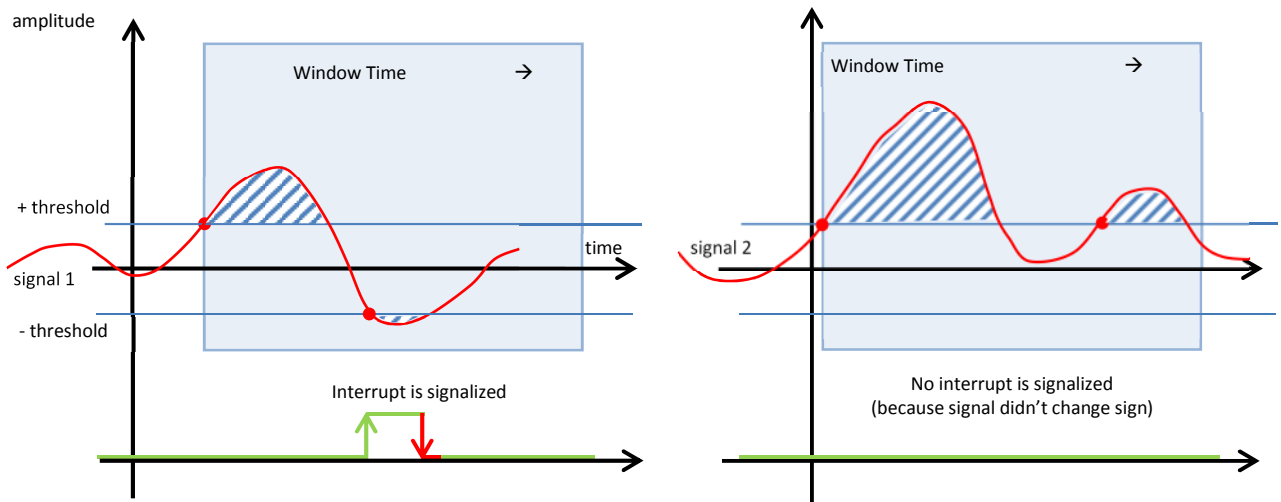


Figure 5 Signal Example for Pulse count = 2, Register Value[12:11] = 01b = 1 dec. and Pulse Detection Mode = 0, Register Value [0] = 0.

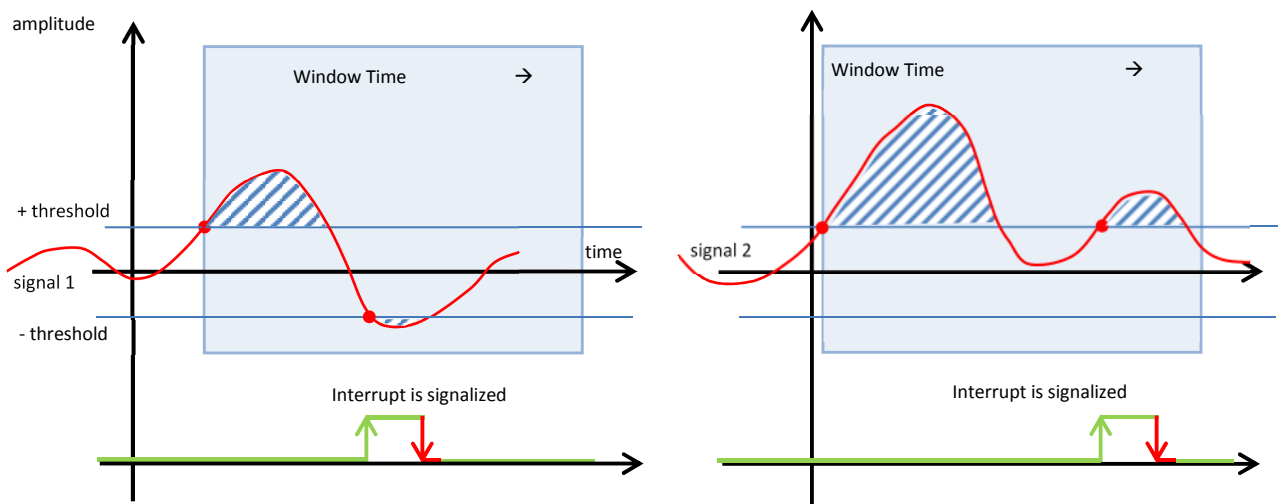


Figure 6 Signal Example for Pulse count = 2, Register Value[12:11] = 01b = 1 dec. and Pulse Detection Mode = 1, Register Value [0] = 1.

Above examples in the two figures illustrate the difference between Pulse Detection Mode set to 0 or 1

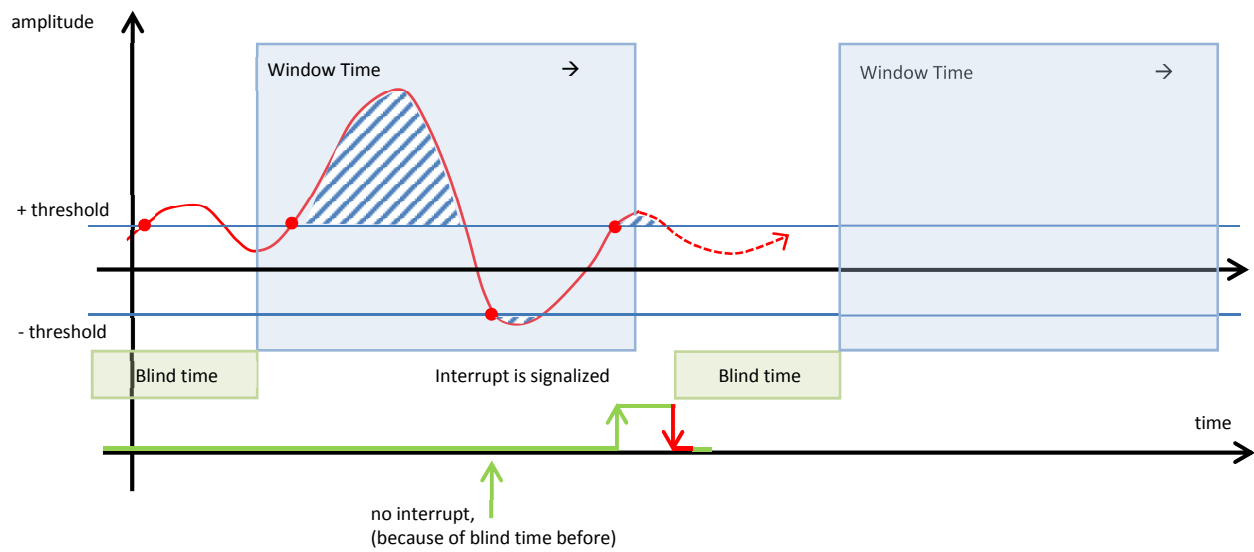


Figure 7

Signal Example for Pulse count = 3, Register[12:11] Value = 10b = 2 dec. and active blind time before and Pulse Detection Mode = 0, Register Value [0] = 0.

Above example shows the effect of the blindtime. The the blind time starts when the interrupt is cleared. When the blind time is elapsed, the window time is resumed.

Example function calls

Some examples for calls of above C-function (fig.2) and their effect

Function Call (parameter hex)	Description
writeregval(0x00000030)	The Wake Up Operation Mode is inactive and positive edges on D/L aren't generated. The output of the PIR signal is only low pass filtered. The host microcontroller can initiate the readout anytime.
writeregval(0x00000010)	The Wake Up Operation Mode is inactive and positive edges on D/L aren't generated. The output of the PIR signal is band pass filtered. The host microcontroller can initiate the readout anytime.
writeregval(0x00304D10)	The Wake Up Operation Mode is active and the LowPower DigiPyro® 2 nd Gen. generates a positive edge on D/L when the PIR signal exceeds the threshold of 24 bit count with a change of sign twice within 6 sec. Another positive edge will not be generated for 1.5 sec. after D/L was set to Low and being released (input of host microcontroller is high impedance).
writeregval(0x00C01710)	The Wake Up Operation Mode is active and the LowPower DigiPyro® 2 nd Gen. generates a positive edge on D/L when the PIR signal exceeds the threshold of 96 bitcount with a change of sign three times within 8 sec. Another positive edge will not be generated for 0.5 sec. after D/L was set to Low and being released (input of host microcontroller is high impedance).

2.1.3 Direct Link Data Output

Data readout via Direct Link (D/L) is always initiated by the host. The entire data packet consists of 40 bit in total.

Bit[39] is indicating an Out of Range condition

Bit[38:25] are holding the signal of the selected voltage source: (PIR-BPF, PIR-LPF or Temperature Sensor).

Bit[24] to Bit[0] are holding the contents of the internal configuration register as set via SERIN. This can be used to verify if the configuration setting is correct.

The readout can be stopped after any bit, it is not required to read all bit (see 2.2.3).

Bit-No	Register	Name	Remarks
[39]	[0]	/Out of Range	A Low Level indicates that the detector is currently in an Out Of Range condition or that there had been such in the time since the last reading was taken
[38:25]	[13:0]	Signal	Voltage selected by Filter Source
[24:0]	-	Settings	Register values as set in the configuration register

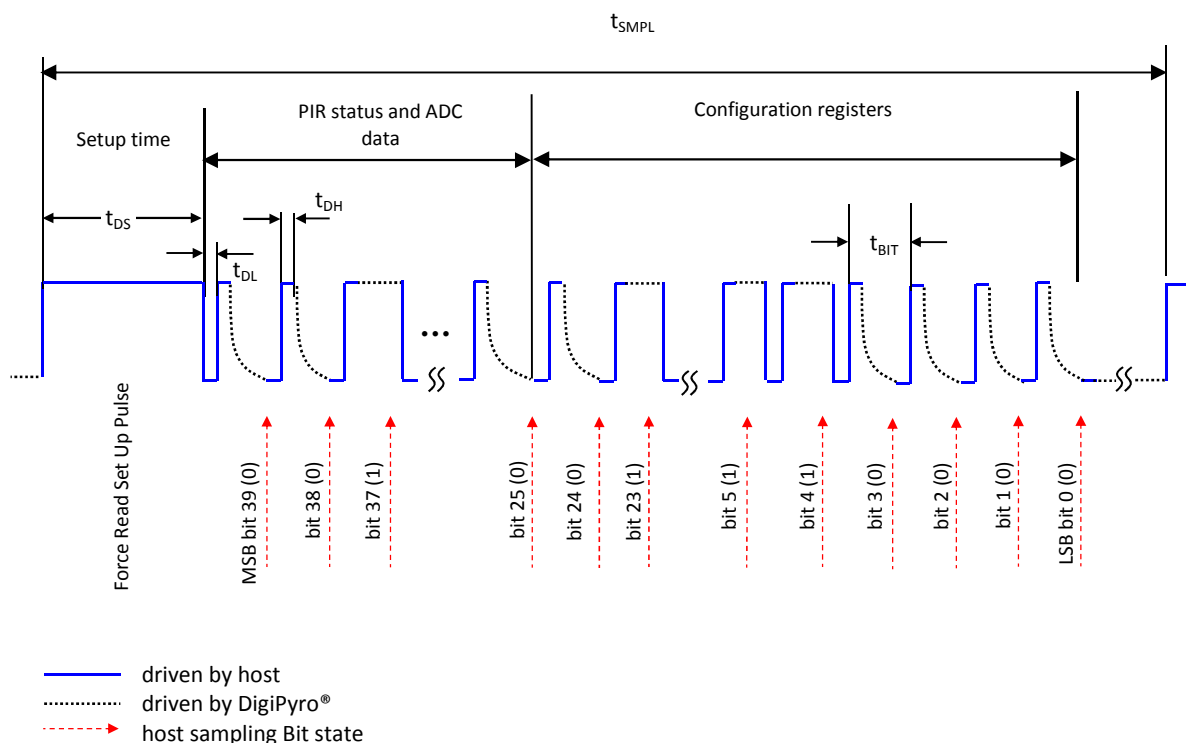


Figure 8 Serial Data Read-Out Sequence

2.1.4 Description of the Read Out Sequence

Data readout is always initiated by the host. It is required to first generate a pulse of at least 3 clock cycles¹ (setup time approx. $t_{DS} = 110\mu s$ min.). Subsequently, the host must generate a Low to High transition prior to reading the state of a bit from D/L. The time for the Low and the High states of the transition (t_{DL} , t_{DH}) should be in the range between 200 – 2000 ns. After the host has generated the Low to High transition, D/L must be released (host controller sets the pin to high impedance input). After a certain time ($t_{BS} = t_{BIT} - t_{DH} - t_{DL} - t_{RP}$ ²) the bit state can be read. It is the time that is required for the signal to safely settle to the correct level representing the bit state (typically Low). Typical values are in the range of 2 - 10 μs and depend on Vdd, pcb layout, line capacitance and resistance etc. Optimum values are to be determined empirically. Repeat the described sequence until all bit are read out.

After the last bit (bit[0] of the configuration register) has been read, the D/L has to be kept actively Low for approx. 500ns (t_{stop}) and subsequently be released (host controller sets the pin to high impedance input).

The read out sequence has to meet the timing requirements described in the Product Specification. It is recommended to read the entire data packet without interruption. If this is not possible, because the microcontroller is loaded with other tasks, it requires special considerations described in the next paragraph.

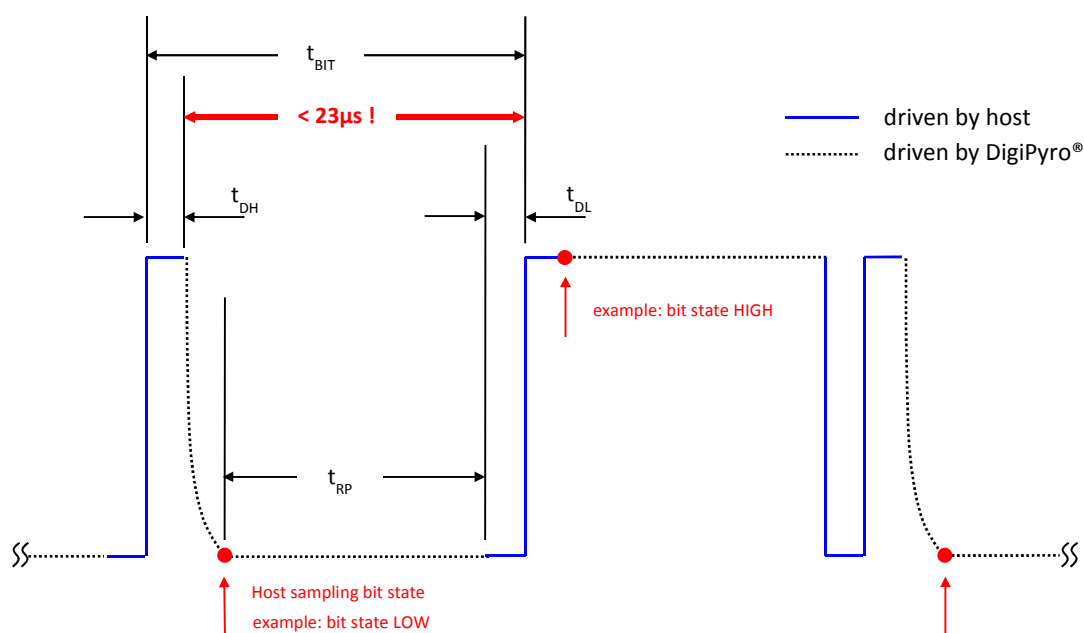


Figure 9 Timing Detail Serial Data Read-Out / Critical parameter $t_{BIT} - t_{DH}$

NOTE: $t_{BIT} - t_{DH}$ must not be longer than 23 μs in order to avoid unwanted data corruption. Also, the setup pulse must always immediately be followed by the first Low to High transition to clock out of the data bits.

¹ The Setup pulse t_{DS} is not needed if D/L is already HIGH for at least 50 μs . (In case of a Wakeup interrupt for example). Output of bit[39] can be then initiated by pulling D/L to LOW and generating the positive transition to HIGH subsequently. For details refer to paragraph "Operation Modes" above.

² t_{RP} is the time needed by the host controller to read and process the bit state. Reading a port pin's state is usually very fast but storing it at the right position of a data variable may take a time that needs to be considered especially when operating the host controller at slower speed.

2.1.5 Interrupted and Partial Readout of a Data Packet

- The read out of a data packet can be interrupted at any bit position when the microcontroller holds D/L High, simply by extending t_{DH} . The data readout can then be resumed by releasing D/L and reading the next bit state after the signal stabilized.

IMPORTANT : Interrupting the readout at D/L Low level is not allowed as it has data corruption as effect when the readout would be resumed again.

Permanent recurring interrupted and resumed readouts likely show signal instabilities and are not recommend for precise data analysis in a forced readout mode.

- Partial Readout (for example skipping the read out of the configuration register) is achieved by reading until the last bit of interest is read, and then the host has to keep D/L actively Low for about 500ns and eventually releasing it again (host controller sets the pin to high impedance input). The next readout may not be started sooner than 2ms after the line was released.

```

#define PIN_IS_INP      0
#define PIN_IS_OUTP     1
#define DLA_DIR         DDRD.2          // Direct Link, port D bit 2 data direction bit
#define DLA_OUT         PORTD.2        // Direct Link, port D bit 2 output
#define DLA_IN          PIND.2         // Direct Link, port D bit 2 input

int          PIRval      = 0; // PIR signal
unsigned long statcfg    = 0; // status and configuration register

void readlowpowerpyro(void) {

    int i;
    unsigned int  uibitmask;
    unsigned long ulbitmask;

    DLA_OUT = 1;                // Set DL = High, to force fast uC controlled DL read out
    DLA_DIR = PORT_IS_OUTP;     // Configure PORT DL as Output
    delay_us(150);

    // get first 15bit out-off-range and ADC value
    uibitmask = 0x4000;        // Set BitPos
    PIRval    = 0;
    for (i=0; i < 15; i++)
    {
        // create low to high transition
        DLA_OUT = 0;           // Set DL = Low, duration must be > 200 ns (tL)
        DLA_DIR = PORT_IS_OUTP; // Configure DL as Output
        #asm("nop")           // number of nop dependant processor speed (200ns min.)
        DLA_OUT = 1;           // Set DL = High, duration must be > 200 ns (tH)
        DLA_DIR = PORT_IS_INP;  // Configure DL as Input

        delay_us(3);           // Wait for stable low signal

        // If DL High set masked bit in PIRval
        if (DLA_IN) PIRval |= uibitmask;
        uibitmask<<=1;
    }

    // get 25bit status and config
    ulbitmask = 0x1000000;      // Set BitPos
    statcfg   = 0;
    for (i=0; i < 25; i++)
    {
        // create low to high transition
        DLA_OUT = 0;           // Set DL = Low, duration must be > 200 ns (tL)
        DLA_DIR = PORT_IS_OUTP; // Configure DL as Output
        #asm("nop")           // number of nop dependant processor speed (200ns min.)
        DLA_OUT = 1;           // Set DL = High, duration must be > 200 ns (tH)
        DLA_DIR = PORT_IS_INP;  // Configure DL as Input

        delay_us(3);           // Wait for stable low signal, tbd empirically using scope

        // If DL High set masked bit
        if (DLA_IN) statcfg |= ulbitmask;
        ulbitmask<<=1;
    }

    DLA_OUT = 0;                // Set DL = Low
    DLA_DIR = PORT_IS_OUTP;     // Configure DL as Output
    #asm("nop")
    DLA_DIR = PORT_IS_INP;      // Configure DL as Input

    PIRval &= 0x3FFF;           // clear unused bit

    if (!(statcfg & 0x60)){
        // ADC source to PIR band pass
        // number in 14bit two's complement
        if(PIRval & 0x2000) PIRval -= 0x4000;
    }

    return;
}

```

Figure 10

Example C Code for a host microcontroller to implement reading a data packet to out, PIRval and statcfg

2.1.6 Example Flow Chart

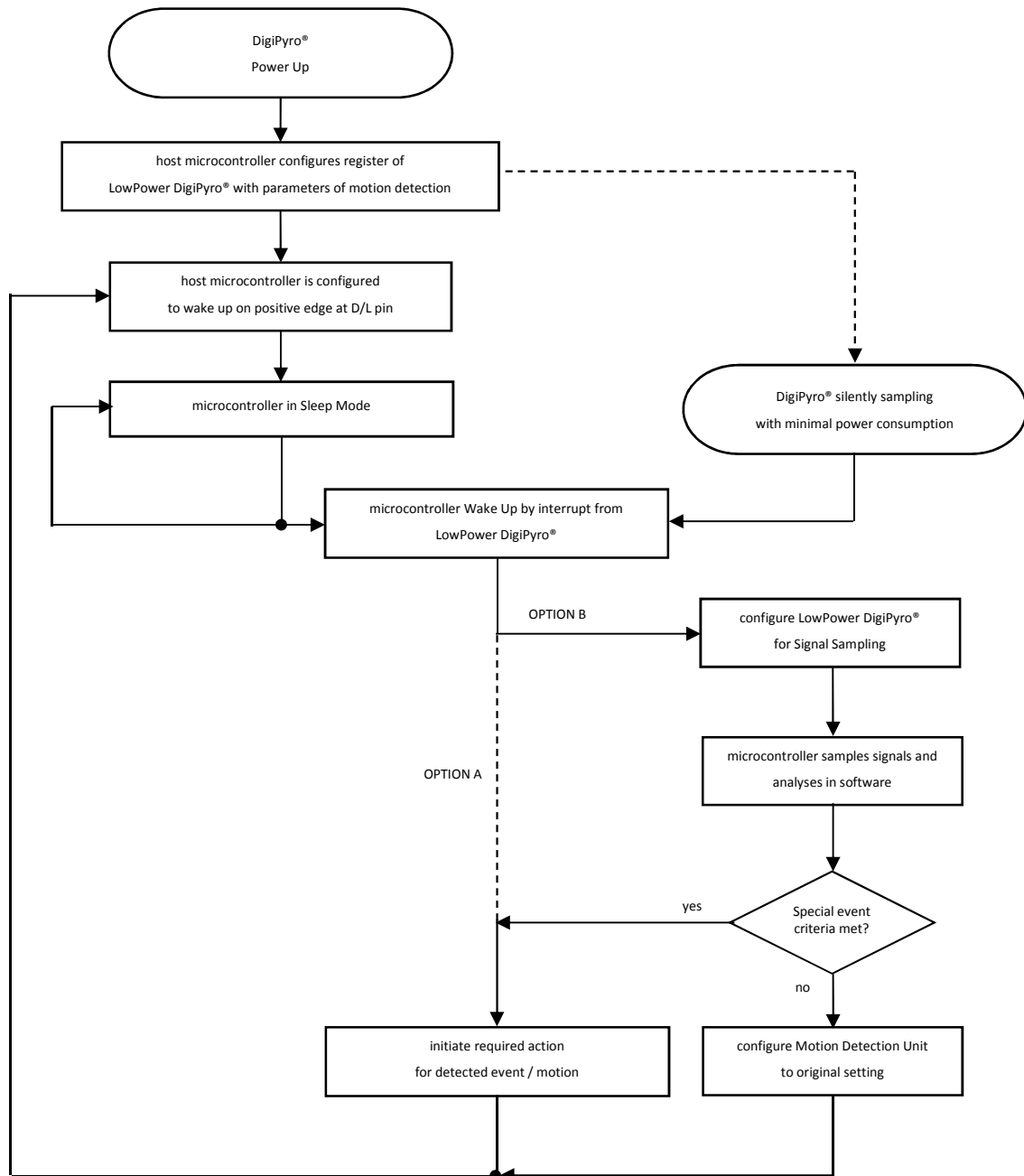


Figure 11 Example flow chart for an entire system employing a LowPower DigiPyro®

Among other possible ways of operation, there are two basic principles shown above to use the LowPower DigiPyro® 2nd Gen. for detecting an event or motion.

In OPTION A, all required signal analysis is handled by the LowPower DigiPyro® 2nd Gen. while the microcontroller is sleeping. The interrupt wakes up the microcontroller, which can immediately execute the desired actions (turn ON light, etc.). Advantages are most simple overall system design and lowest possible power consumption.

In OPTION B, the microcontroller will be woken up by the LowPower DigiPyro® 2nd Gen., however, first will sample signals from the Low Power DigiPyro® 2nd Gen. and perform additional software processing to decide if the desired actions shall be

executed or not. The advantage of Option B is higher flexibility in defining event criteria while still having low power consumption overall.

2.1.7 Switching between the channels

The different levels and filter characteristics need to be considered when changing between the filter source for the readout (PIR band pass, PIR Low Pass or Temperature Sensor).

A transient in the data readout is almost negligible when switching between the PIR Low Pass and the PIR Band Pass source setting. The MUX at the ADC input remains at the same channel. LowPass and High Pass are running concurrently forming together a Band Pass Filter (referring to Product Specification Fig.: 1). The change is only between reading the value before or after the High Pass filter.

When switching from or to the Temperature a transient is likely to be observed. The temperature channel may not be at the same level as the PIR value and the filters need to adapt from PIR to Temperature Sensor and vice versa. Filter time constants are approx. $\tau_{TP} = 20\text{ms}$ and $\tau_{HP} = 360\text{ms}$ (when using the default of 0.4Hz cutt off).

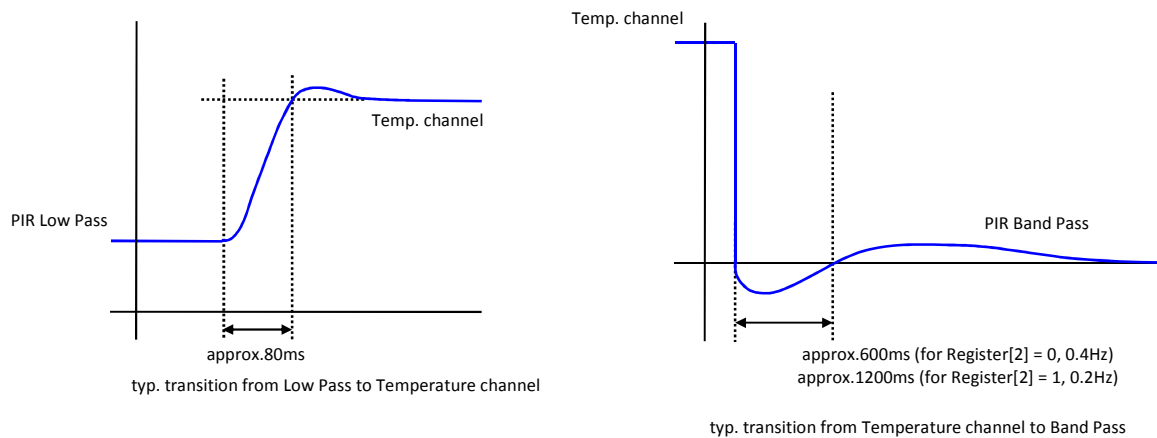


Figure 12 Typical signal transitions when changing the Filter Source.

2.2 Electrical Connection / Design Recommendation

2.2.1 Thermal aspects

Temperature effects should be avoided. Thermal disturbing components shall not be placed close to the detector. This especially applies to heat generating devices like microcontrollers at high operating frequencies, LEDs, etc.

The customer is strongly encouraged to minimize all thermal disturbances and temperature gradients at the detector in the application to avoid triggering the Out-Of-Range reset as it may cause the application to produce false alarms. Examples for sources of disturbance:

- Moving air
 - Sunlight
 - Heat flow on PCB
 - etc.
- Detector must be protected in a housing and maybe rubber ring around the cap i.e.
 Second filter in front of the detector might be required.
 Spacer below baseplate or PCB with slots and thin bridges can be helpful.

2.2.2 Electronic aspects

Variations of the power supply voltage should be avoided. The detector's PSRR is in the range of 60 dB, but in case of induced signals in the 100mV range some signal modulation may occur.

The pcb layout should avoid routing other signals underneath or close to the LowPower DigiPyro® 2nd Gen. sensor package.

At a given condition (circuit design) with strong distortion (by HF transmitter in the 2,4 GHz band for example), the individual components selection, placement and connection become relevant in view of the EMI susceptibility of the LowPower DigiPyro® 2nd Gen.

On the sketch below, the potential contribution factors are illustrated for example.

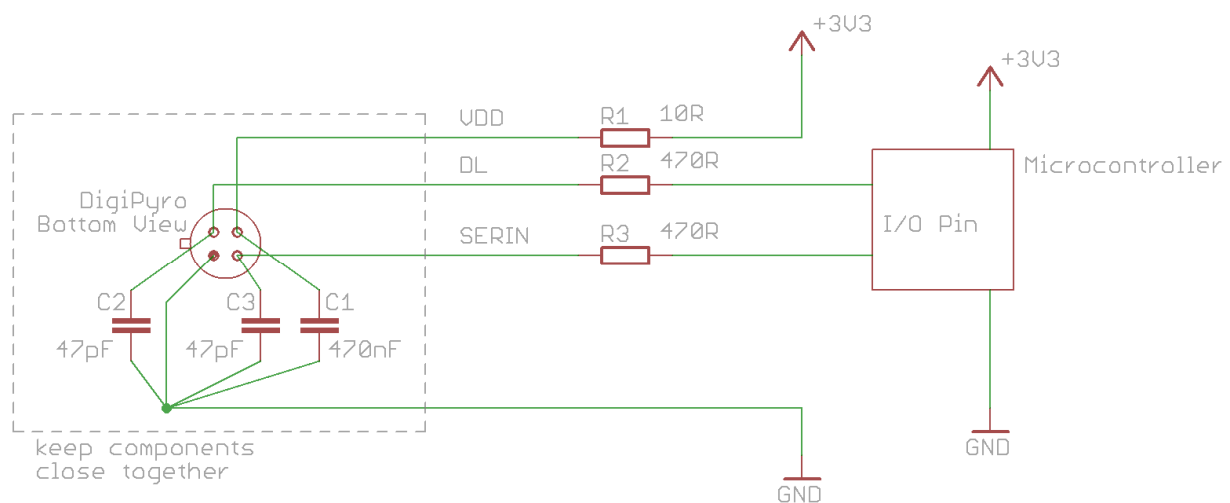


Figure 13 Schematics diagram interfacing the DigiPyro with the host microcontroller

The framed area is considered critical

- Keep R1, R2, C1 and C2 as close as possible to the LowPower DigiPyro® 2nd Gen.
- Longer lines may lead to resonance effects. Lines should be kept as short as possible.
- Branch lines are to be avoided for GND as well as for the Direct Link and VDD.
- R2 and R3 must be less 2kOhms to ensure proper signal levels for the LowPower DigiPyro® 2nd Gen.

An additional electrolytic capacitor may be added parallel to C1. If EMI susceptibility remains an issue, try to change values to find out what causes the sensitivity. If readout timing is constant and an additional electrolytic capacitor is fitted parallel to C1, one can increase R1 to more than 100 Ohms.

The value of C2 directly influences the bit settling time and hence the read out speed.

Gross rule of thumb to estimate the value for C2:

C2/sec. = 20 μ F/sec.	(VDD = 3V)
C2/sec. = 12 μ F/sec.	(VDD = 1.8V)

Example for a required settling time of 10 μ s:

C2 <= 10 μ s x 20 μ F/sec. <= <u>200 pF</u>	(VDD = 3V)
C2 <= 10 μ s x 12 μ F/sec. <= <u>120 pF</u>	(VDD = 1.8V)

Best value has to be determined and confirmed empirically.

The configuration interface SERIN is operating at a lower frequency than Direct Link and may accept other capacitor values as Direct Link. If EMI performance is acceptable, values for the RC combination at SERIN may also use the same values as for Direct Link. Since influence of HF is difficult to assess, the circuit should be modified step by step attentively with the recommended means to verify the effectiveness of the individual contribution factors. Tiny modifications on placement and geometry may have high influence. Best performance is typically found in experiments with different design variants.

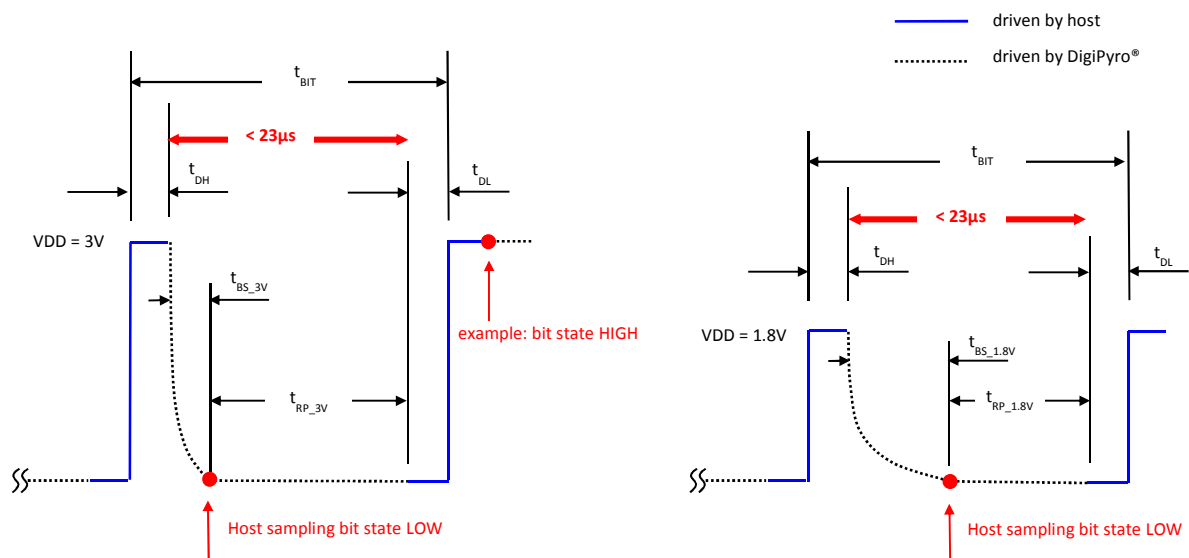
No component value may be used such way the timing requirements for Direct Link and SERIN as stated in the Product Specification are not met. The host microcontroller's output must be able to drive the RC combination and the lines to ensure correct signal levels and timing at the DigiPyro's inputs.

2.2.3 Operation at 1.8V supply voltage

Advantage of operating at 1.8V is reduced power consumption as compared to the operation at 3V for example. On the other side, certain parameters may become more critical and require special attention.

Host controllers typically operate at 1.8V with lower speed than at 3V or 5V. Data processing and the execution of the data readout may also take a longer time. The DigiPyro® as well also needs a longer time to drive the DirectLink interface during data readout. It can especially be observed in a longer Bit Settling time t_{BS} when operating at a lower VDD.

Below diagrams qualitatively illustrate the relation between VDD = 3V and 1.8V when the LowPower DigiPyro® 2nd Gen. drives DirectLink to Low.



$t_{BS_1.8V} > t_{BS_3V}$, hence the time t_{RP} , left for the host controller to read and process a bit state, becomes shorter as the t_{BS} gets longer.

Exact values can only be determined in the actual setup of the application. Beside device tolerances, main contributors to t_{BS} are line impedances, leakage currents or additional EMI components as shown in the paragraph above.

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