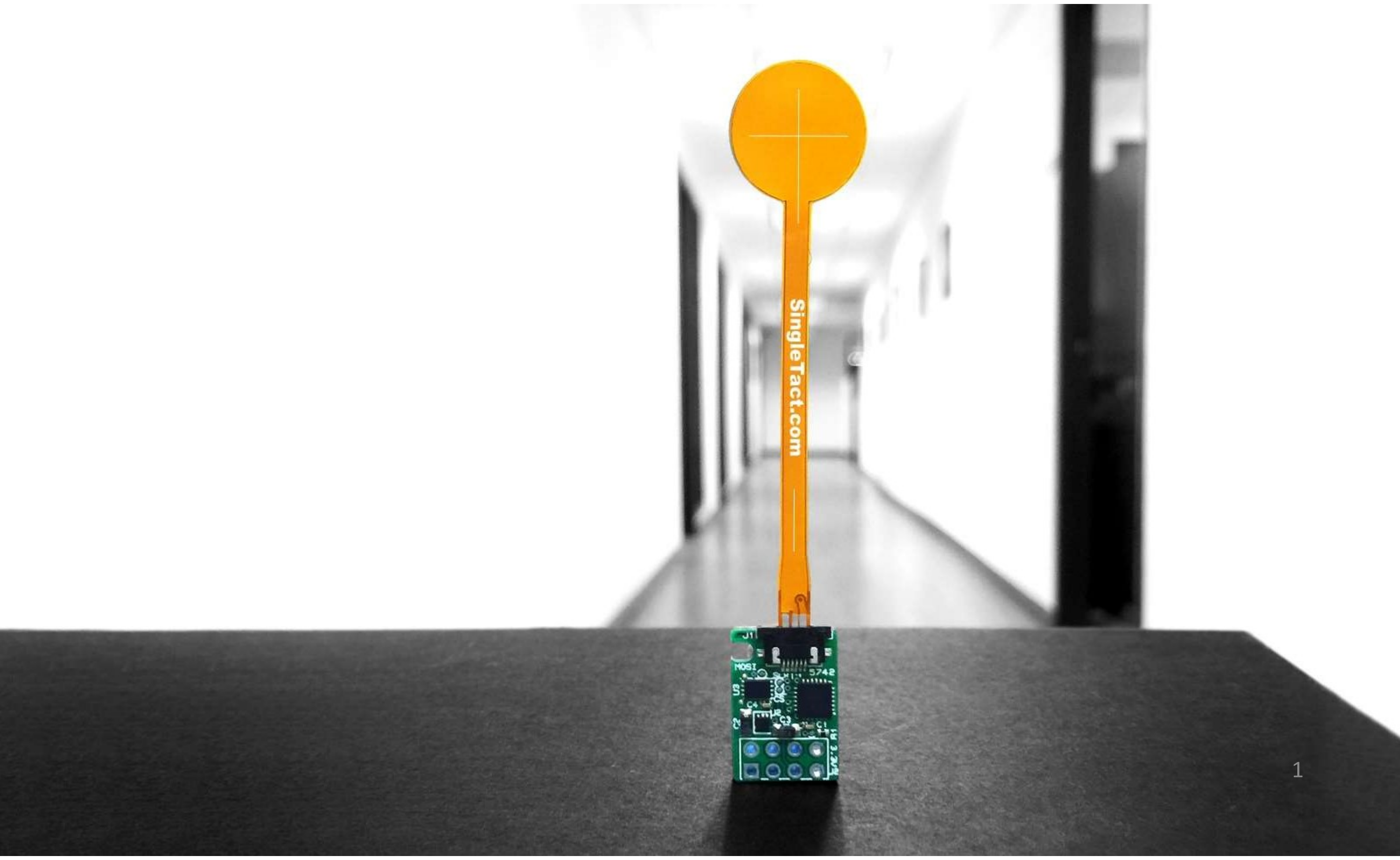
SingleTact
MINIATURE FORCE SENSORS

USER MANUAL

EXPERIENCE INCREDIBLE PERFORMANCE



CONTENTS

SingleTact
MINIATURE FORCE SENSORS

1

1.INTRODUCTION

The SingleTact is a single element sensor that accurately and reliably measures force. The interface board features a 2V analog output for easy DAQ integration and an I²C interface for embedded systems. This document provides all the information necessary to interface with SingleTact including a sample Arduino digital interface and a PC data acquisition app. The open-source code can be downloaded from: https://goo.gl/zRDBsk. An overview of the Arduino based SingleTact system is shown in Figure 1. The SingleTact can be used in a number of ways outlined in Table 1.

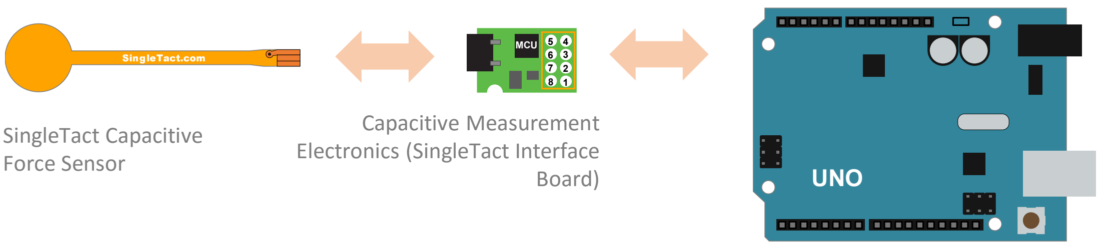


Figure 1: Arduino based SingleTact System Overview

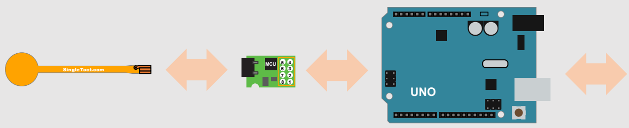
	Use Case	System Overview	
1	Force Measurement		Analog output. Connect to multimeter, oscilloscope or data acquisition card
2	Evaluation/ Force Measurement*1		PC acquisition software
3	Customer Integration*2		I²C digital uutput. Interface to customer electronics
4	Customer Integration*3		Customer reads capacitance using their own circuitry

Table 1: The four SingleTact use cases

*1 – In addition to the data acquisition software, a .NET library is provided for simple integration into a customer's own software suite.
*2 – Supports over 100 SingleTact interface boards. Customers can modify interface board firmware as needed. Source code is provided in Section 2.4.
*3 – Customer may choose to use the Silicon Labs C8051F717 Capacitance to Digital converter that is used in the SingleTact Interface. The source code is provided in Section 3.4.

2

2.1 Pinout

The sensor is plugged into the FFC connector on the green interface board (***the sensor connector pads should face upward***). The connections are outlined in Table 2. The electrical parameters are outlined in Table 3.

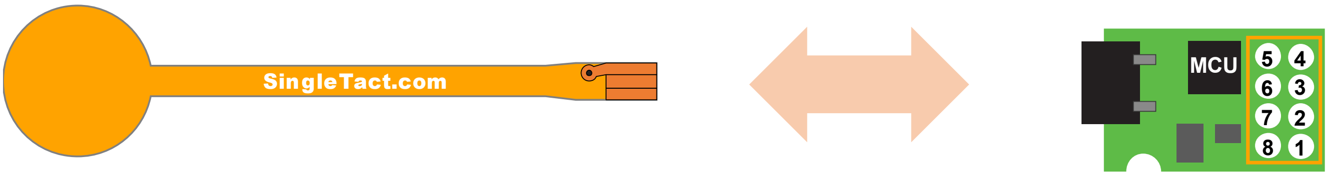


Figure 2: SingleTact configuration

Connection	Pin Number		Connection
Programming (Clock)	5	4	Programming (Data)
I²C Interface (SDA)	6	3	I²C Interface (SCL)
Frame Sync (Pulse for each new measurement)	7	2	Analog output (2V swing, 0.5 to 1.5V = full scale range)
Ground	8	1	V_{cc} (3.7V to 12V)

Table 2: The SingleTact interface board pinout.

Parameter	Value
Supply Voltage	3.6 - 12V
I2C Clock	100kHz or 400kHz
Analog Range	0 – 2 V (FSR output from 0.5V to 1.5V)
Digital Logic	3.3V
Sensor update rate (I²C or Analog)	>140Hz (depends on C8051F717 settings)

Table 3: Electrical parameters

2.2 ANALOG INTERFACE

As shown in Figure 3, the analog output swings from 0 to 2V, with valid outputs ranging from 0.5V to 1.5V.
As pressure increases beyond the full scale range (FSR), the output increases to 2V and then saturates.
An output below 0.5V may indicate negative pressures, which occur when the sensing area is under tension. This should be avoided since it can damage the internal structure of the sensor. Note that if the sensor is unloaded and the output is still under 0.5V, then a shift in the sensor's baseline has occurred. You can reset the baseline using the sensors digital interface, which is specified in Section 3.

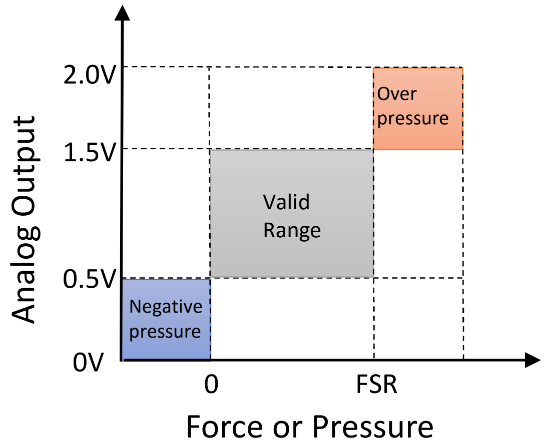


Figure 3: SingleTact analog output

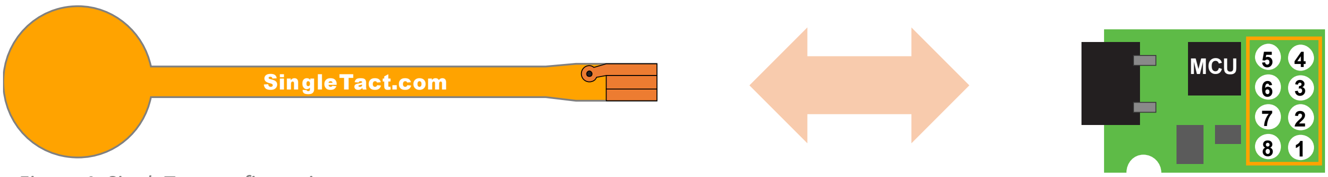


Figure 4: SingleTact configuration

The analog output connections are detailed here below:

Connection	Pin Number		Connection
No connection	5	4	No connection
No connection	6	3	No connection
No connection	7	2	Analog output (2V swing, 0.5 to 1.5V = full scale range)
Ground	8	1	V_{cc} (3.7V to 12V)

Table 4: Analog connections

2.3 PC INTERFACE

An Arduino UNO board can be used to provide a USB interface to SingleTact.

Download the PC Interface from: https://goo.gl/40CqZB
The demo application is available from Github: https://goo.gl/L6kYCs

Connect the sensor to the Arduino board as follows:

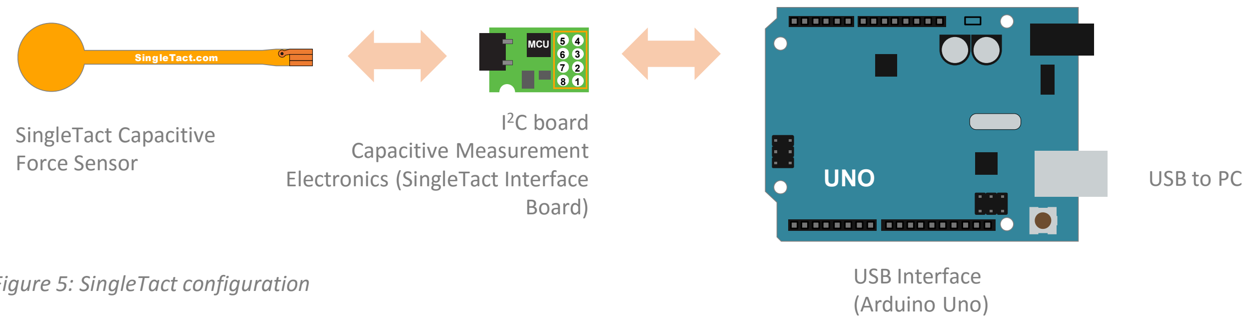


Figure 5: SingleTact configuration

SingleTact Connection	Pin Number		SingleTact Connection
No connection	5	4	No connection
Arduino UNO A4	6	3	Arduino UNO A5
No connection	7	2	No connection
An Arduino GND pin	8	1	An Arduino 5V pin

Table 5: Shows connections between SingleTact and Arduino UNO. The SingleTact is powered from an Arduino 5V line and is connected to the Arduino I2C bus.

Please refer to Section 3.1 for instructions on flashing the Arduino.

Run SingleTact.exe to bring up the demonstration application:

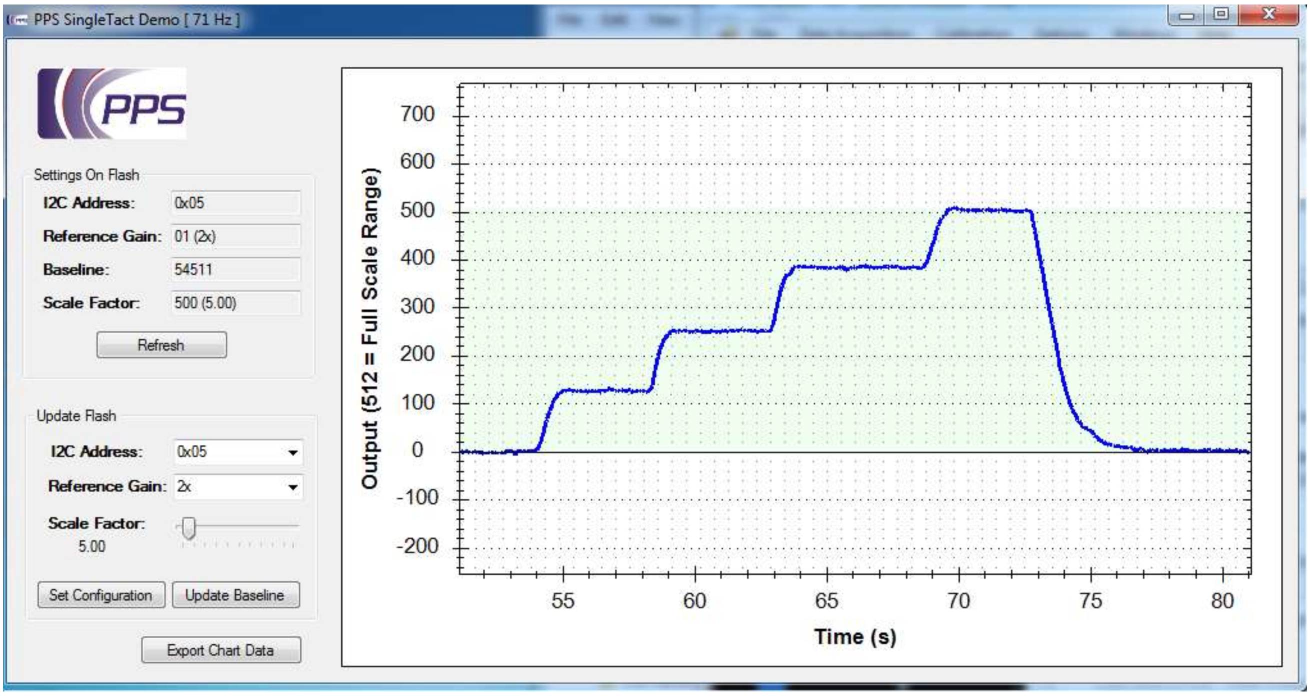


Figure 6: Demo PC DAQ software

The demonstration application can be used to change the sensor's I^{2}C address and modify its capacitive sensing settings. For more information on these settings please refer to Section 3.

2.4 I²C INTERFACE

The SingleTact I²C interface supports standard (100 kbits/s) and high speed (400 kbits/s) clock rates and a 7 bit address width. The SCL and SDA lines should be pulled up to the bus voltage, which can be between 3V and 5V.

The SingleTact software architecture is based on a 192 byte register which is detailed in Table 6. The first 127 bytes of memory are used to store settings in flash (and are therefore persistent after a power cycle). The sensing results are available from byte 128. A more detailed breakdown of the register is shown in Tables 7 and 8.

The interface board will always respond to two I²C addresses: 0x04 ***and*** the address specified in flash. Since the default flash setting is 0x04, the interface board flash address has to be changed before multiple boards can be used on the same I²C bus.

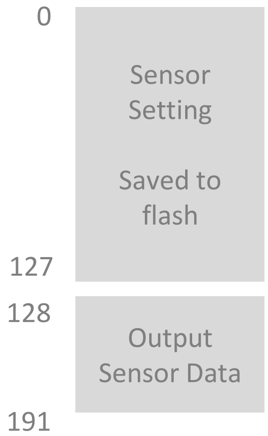


Table 6: Register layout

The capacitive sensor settings are outlined in the C8051F717 datasheet.

Internally, the C0851F717 measures capacitive to 16 bit precision. This is scaled to a 12 bit digital and 2V analog output as per the following calculation:

$$SingleTact\ Output = \frac{\text{Raw}\ capacitance - Baselin\ \ capacitance}{Digital\ scaling\ value} + 255$$

The digital scaling value is a 2 byte number stored at register locations 10 and 11 (Table 7). For increased precision, the digital scaling value resolution is in 0.01 increments. This means that 100 equals unity scaling. The 255 offset provides the facility for a negative swing.

The internal capacitance to digital converter (CDC) operates at 140 to 4000 Hz depending on the capacitance sensor settings (in particular the number of accumulations). Each time the CDC completes a measurement the output register is updated, the frame index increases by one and a pulse is produced on the frame synchronization output pin. A timestamp is calculated on the C0851F717, but since there is no crystal oscillator on the SingleTact interface board, this timestamp is not stable and should only be used as a course estimate.

BYTE	SETTING
0	I2C Address (4-127)
1	User configurable serial number MSB
2	User configurable serial number LSB
3	Reserved
4	Reserved
5	Capacitive Sense (Accumulator) Default 0x04 *1
6	Capacitive Sense (Reference Gain) Default 0x01 *1
7	Reserved
8	Capacitive Sense (Discharge Time) Default 0x03 *1
9	Capacitive Sense (Output Current) Default 0x00 *1
10	Output digital scaling MSB
11	Output digital scaling LSB
12	Number of elements, must be 1
13	Reserved
14	Delimiter – leave as 0xFF
15	First element to scan, set to 0
16-38	Unused for SingleTact
39	Delimiter – leave as 0xFF
40	Sensor baseline MSB
41	Sensor baseline LSB
42-90	Unused for SingleTact
91	Delimiter – leave as 0xFF
92-127	Unused

Table 7: Sensor settings layout in main register. These are stored in flash and loaded each time the SingleTact is powered on.
**1 Please consult* C8051F717 datasheet for more information

BYTE	SETTING
128	Frame index MSB (increments on each new reading)
129	Frame index LSB (increments on each new reading)
130	Sensor Timestamp MSB (0.1ms increments) *1
131	Sensor Timestamp LSB (0.1ms increments) *1
132	Sensor output MSB
133	Sensor output LSB
134 - > 191	Unused

Table 7: Sensor readings layout in main register. These are updated at >140Hz (depending on capacitance sensor settings). The frame sync digital output pulses each time these change.

**1 This should only be used as a course estimate as it is liable to drift.*

I^2C transmissions are limited to 32 bytes. The packet layout is detailed below.

BYTE	To Sensor
0	Read Request (0x01) or Write (0x02)
1	Read/write location in register
2	Number or bytes to read/write
3 -> (N-1)	Data to write 0 bytes for read request
N (max 31)	0xFF – signifies end of packet.

Table 8: I2C Packet layout (to sensor)

There are only two master to slave I^2C commands, “read request” and “write”, which are encoded in the first byte of the outgoing I^2C transmission. The second and third bytes represent the read location and length respectively.

An I^2C slave read transmission is typically preceded by a master to slave read request command that sets the read location. If no such read command is issued, the read location defaults to 128 (the sensor output location).

Data can be read from anywhere in the register (addresses 0 – 191), but can only be written to the first 128 bytes. Reading or writing out of this valid range will fail.

Bytes 3 to N-1 (where N is the packet length) contain any data to be written to the main register. This command updates the internal flash memory, so the new settings are persistent beyond a power cycle.

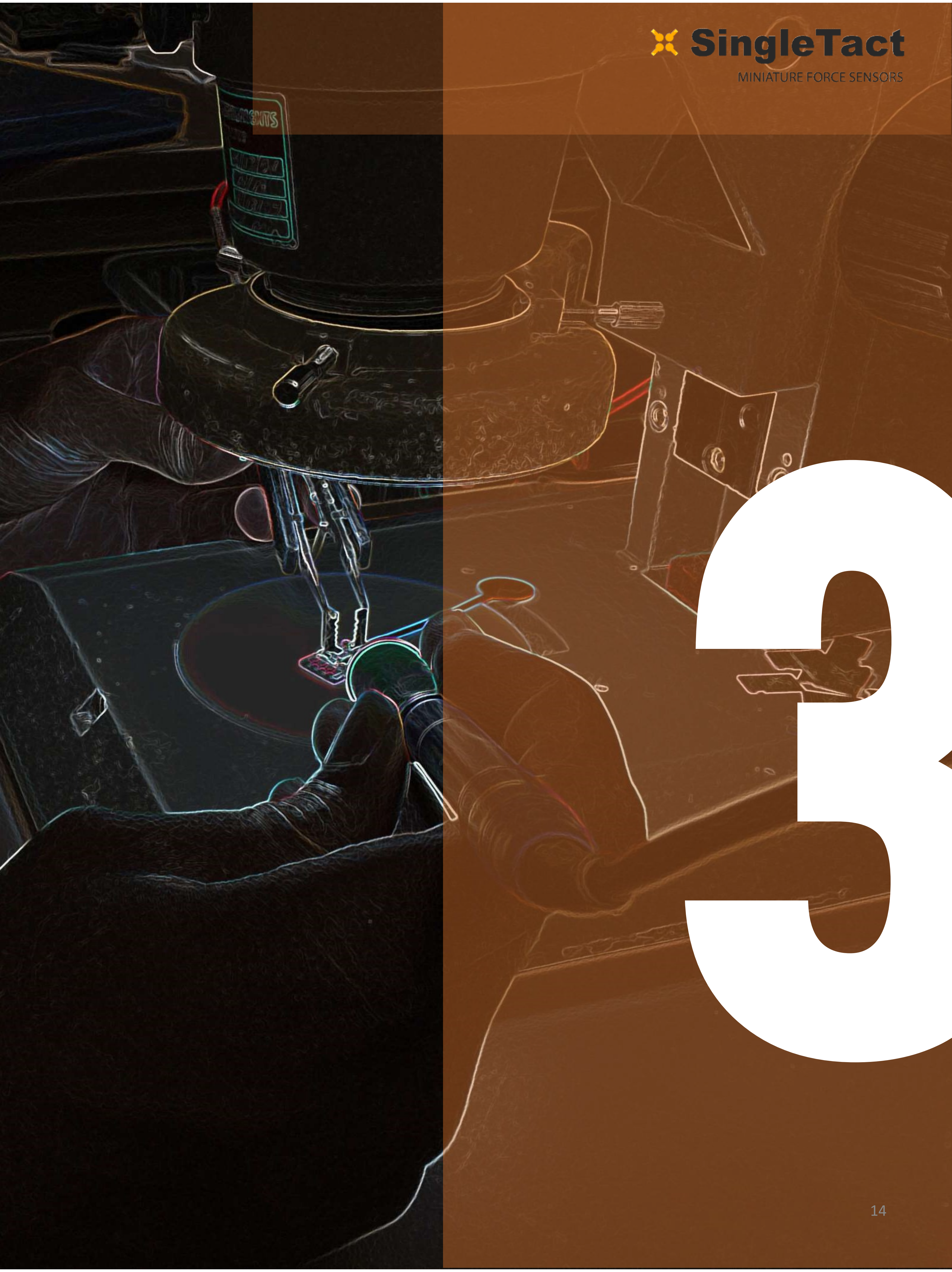
The final byte must be 0xFF to signify the end of the packet.

I^2C slave read commands simply contain the main register data up to the number of requested bytes (32 max).

BYTE	From Sensor
0-31	Main Register Data

Table 9: I^2C *Packet layout (from sensor)*

The frame synchronization output pin (7 – see Figure 2) goes high when a new measurement is available. This can be used to synchronize the I^2C communications channel to the capacitance sensor. Alternatively, since the frame index increments with each new frame, the sensor can be polled as quickly as possible over I^2C, throwing away duplicate data where the frame index has not incremented.



3

3.1 FLASHING AN ARDUINO

This process outlines how to flash Arduino with SingleTact firmware.

1. Download and install the Arduino Software from : https://goo.gl/hhQIOK
2. Download the Arduino firmware from GitHub: https://goo.gl/mZ03Uu
3. Connect the Arduino to the PC using the supplied USB cable.
4. Open the Arduino IDE software:

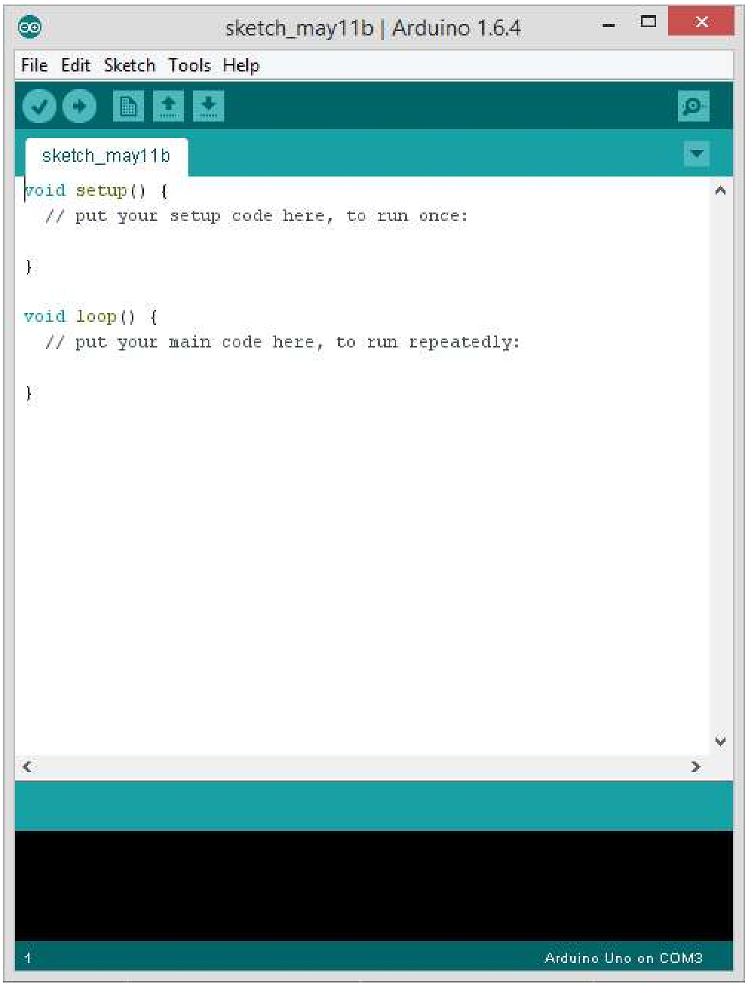


Figure 7: Arduino integrated development environment

1. Go to File->Open and open "SingleTactDemo.ino"
2. Go to Sketch->Include Library->Add .zip Library and select "Timer1.zip"
3. Go to Sketch->Verify/Compile. If you receive an error make sure the Arduino is selected under Tools->Port.

You are now ready to run the demonstration application detailed in the previous Section.

3.2 AN ARDUINO EXAMPLE

This section details the Arduino firmware required for the PC DAQ outlined in Section 2.3.

The PC to Arduino interface is setup to mirror the I^2C interface, keeping the Arduino code as simple as possible. The structure is shown in the following diagram:

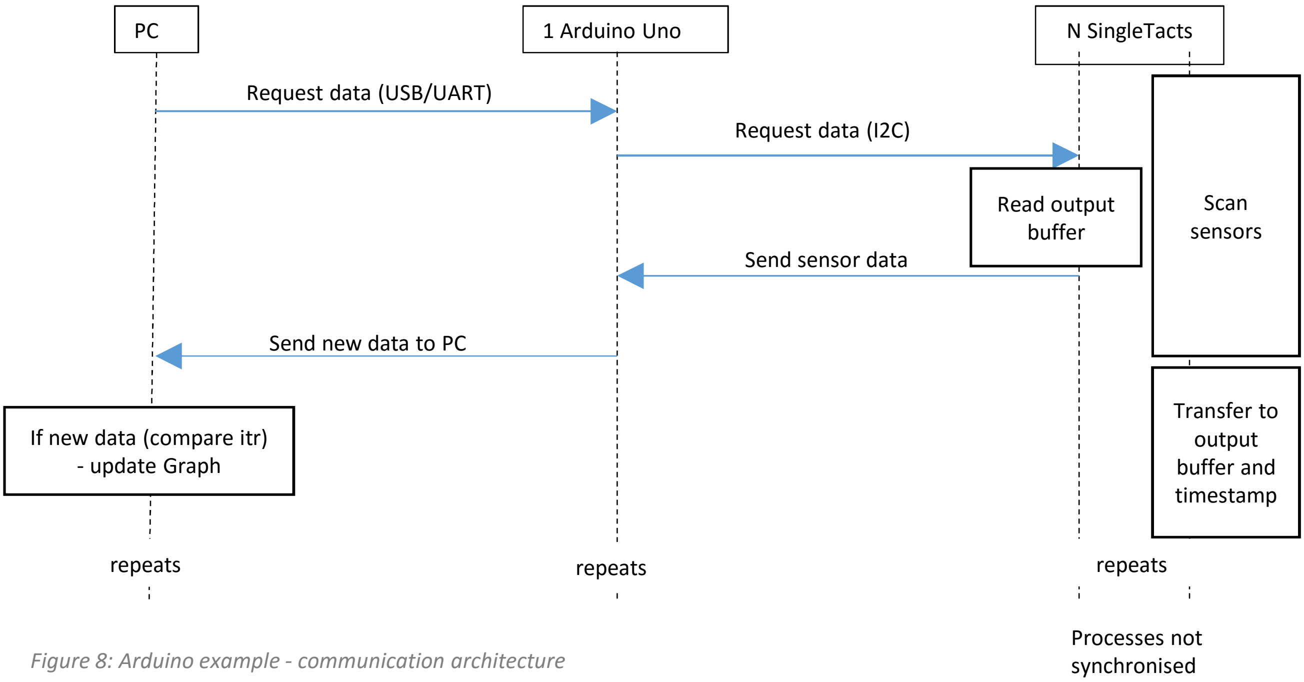


Figure 8: Arduino example - communication architecture

The Arduino firmware functions as follows:

*1 Note, the Arduino contains a crystal oscillator so it is able to produce a more accurate timestamp than the SingleTact interface board.

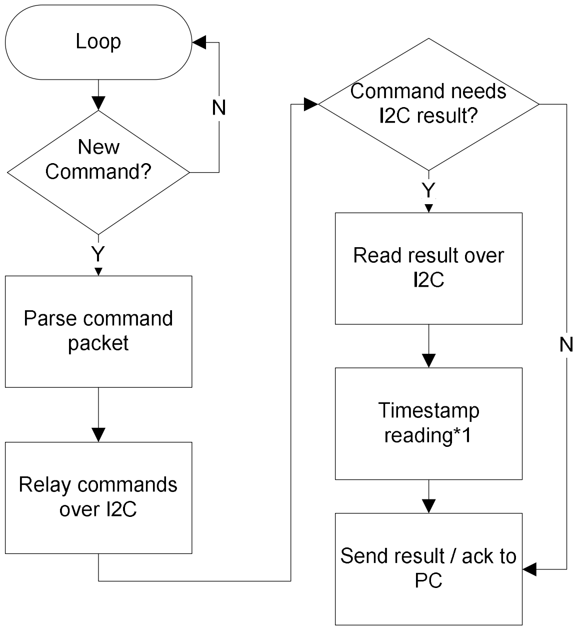


Figure 9: Arduino firmware flow diagram

The PC DAQ code functions as follows:

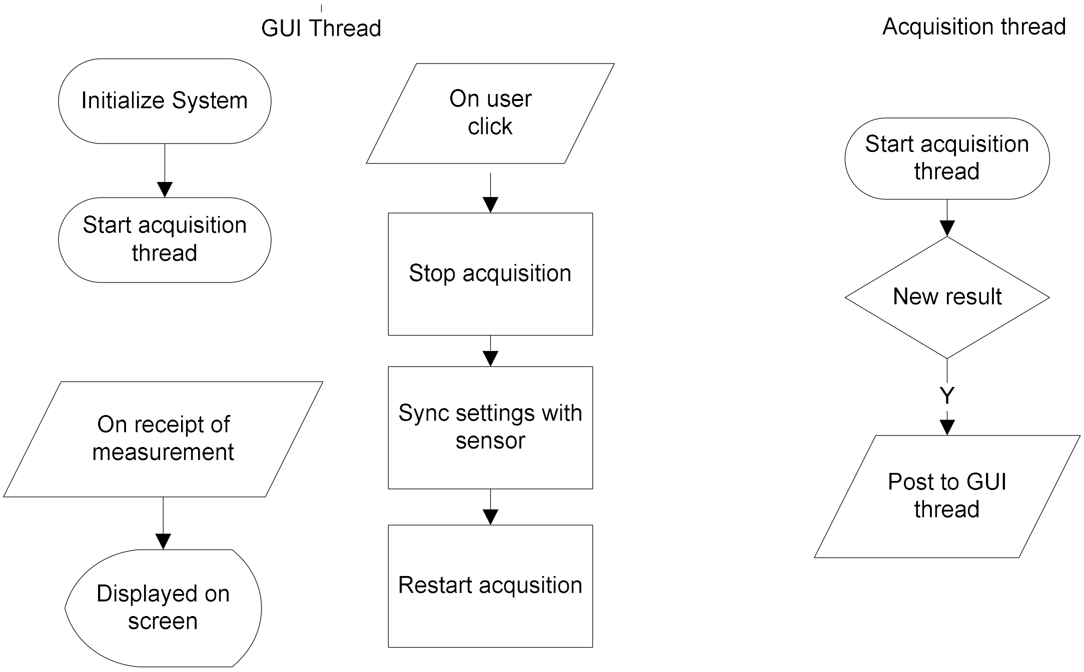


Figure 10: PC DAQ example code

On the PC, the Arduino appears as a virtual serial device. Data is sent to/from the Arduino using serial interface, such as the one available in .NET.

The serial commands, which encase the raw I²C commands (shown in blue), are outlined in the following tables. Headers and footers are added to easily deliminate serial packets. A timeout can be specified for I²C transfers. The Arduino calculates a timestamp for each packet using the Arduino's crystal controlled oscillator.

BYTE	From Arduino to PC
0	Header = 0xFF
1	Header = 0xFF
2	Header = 0xFF
3	Header = 0xFF
4	I2C address of sensor
5	Timeout (in 100ms increments)
6	ID (echoed in reply)
7	Read (0x01) or Write (0x02)
8	Read/ write location
9	N bytes to read/ write (max 32)
10->(10 + N-1)	Data to write 0 bytes for read request
11 + N	0xFF – signifies end of packet
12 + N	Footer = 0xFF
13 + N	Footer = 0xFF
14 + N	Footer = 0xFF
15 + N	Footer = 0xFF

Table 10: Serial packet structure (to Arduino)

BYTE	From Arduino to PC
0	Header = 0xFF
1	Header = 0xFF
2	Header = 0xFF
3	Header = 0xFF
5	1 if timeout exceeded
6	ID (echoed transmit ID)
7	Timestamp MSB
8	Timestamp
9	Timestamp
10	Timestamp LSB
11	N I2C bytes to be sent (max 32)
12 -> 12+N	I2C data
13+N	Footer = 0xFE
14+N	Footer = 0xFE
15+N	Footer = 0xFE
16+N	Footer = 0xFE

Table 11: Serial packet structure (from Arduino)

3.3 NET INTERFACE

This section details an example .NET DAQ App.

Download the .NET Interface and demo application from GitHub: https://goo.gl/CAZP88

For convenience the low level PC interface is encapsulated in two .NET components.

1. ArduinoSingleTactDriver – The basic Arduino interface. The user must create one of these.
2. SingleTact – There can be multiple SingleTacts each with their own I^2C address.

Creating a SingleTact interface is as simple as:

```
arduinoSingleTactDriver.Initialise(COMport);                //Start Arduino driver
singleTact_.I2cAddressForCommunications = 0x04;             //Set I2C address
singleTact_.Initialise(arduinoSingleTactDriver);      //Start sensor
```

The sensor is read using the following:

```
SingleTactFrame newFrame = singleTact_.ReadSensorData(); //Get sensor data

if (null != newFrame) //If we have data
    {//Process result}
```

Settings can be pulled from the sensor using:

```
singleTact_.PullSettingsFromHardware();
```

and sent to the sensor using:

```
singleTact_.PushSettingsToHardware();
```

The sensor settings can be modified using commands like:

```
singleTact_.Settings.ReferenceGain = ###;
```

3.4 INTERFACE BOARD SOURCE CODE

The interface board source code can be downloaded from GitHub using: https://goo.gl/Qjs62D

Programming the C8051F717 requires a 8 bit programmer, which can be purchased from Digikey (336-1182-ND). Programming requires the Silicon Labs IDE and a free Keil compiler, which can be downloaded from:

http://goo.gl/yJLZh2

The hardware connections are as follows:

Connection	Pin Number		Connection
Programming (Clock) - Programmer pin 7	5	4	Programming (Data) - Programmer pin 4
None	6	3	None
None	7	2	None
Ground - Programmer pin 2 or 4 or 9	8	1	V_{cc} Programmer pin 10

Table 12: Programming connections

For convenience the Silicon Labs 8 bit programmer connector pinout is shown below. For more information consult: http://bit.ly/1V6sCmJ

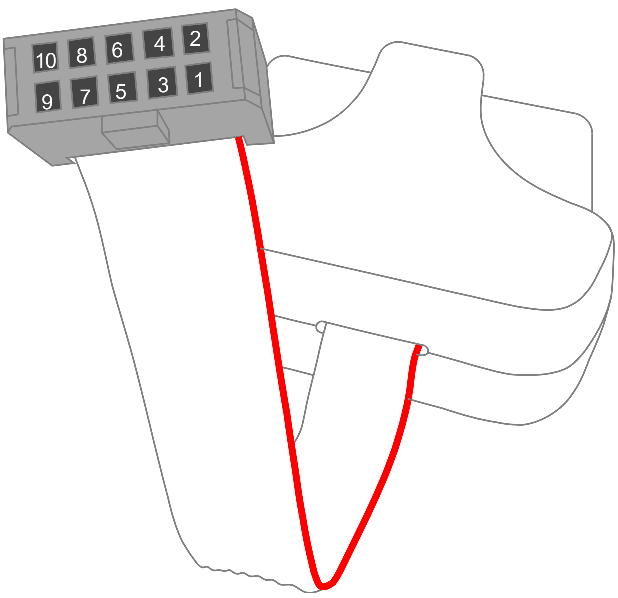


Figure 11: Silicon Labs 8 bit programmer pinout