Application note AN201102

Current Measurement With Evaluation Board



Introduction

Scope

This document gives information on how to use an Insight SiP Evaluation Board to measure the current consumption of a Bluetooth Low Energy module from iSP15, iSP18 and iSP19 series.

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Document Revision History

Revision	Date	Ref	Change Description
R0	16/02/2021	ys pg	Initial release
R1	28/06/2022	pd pg	Document layout update

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1. Recommended Documentation

The following Nordic Semiconductor document and Software Dev Kits are required.

Nordic Semiconductor Document

- nRF528xx Product Specification – make sure you have the most recent version of the appropriate document depending on the module type.

Software Dev kits

- nRF5 Software Development Kit (SDK) which includes precompiled HEX files, source code as well as SES and Keil ARM project files.
- S100 series SoftDevice.

Other Insight SiP documents

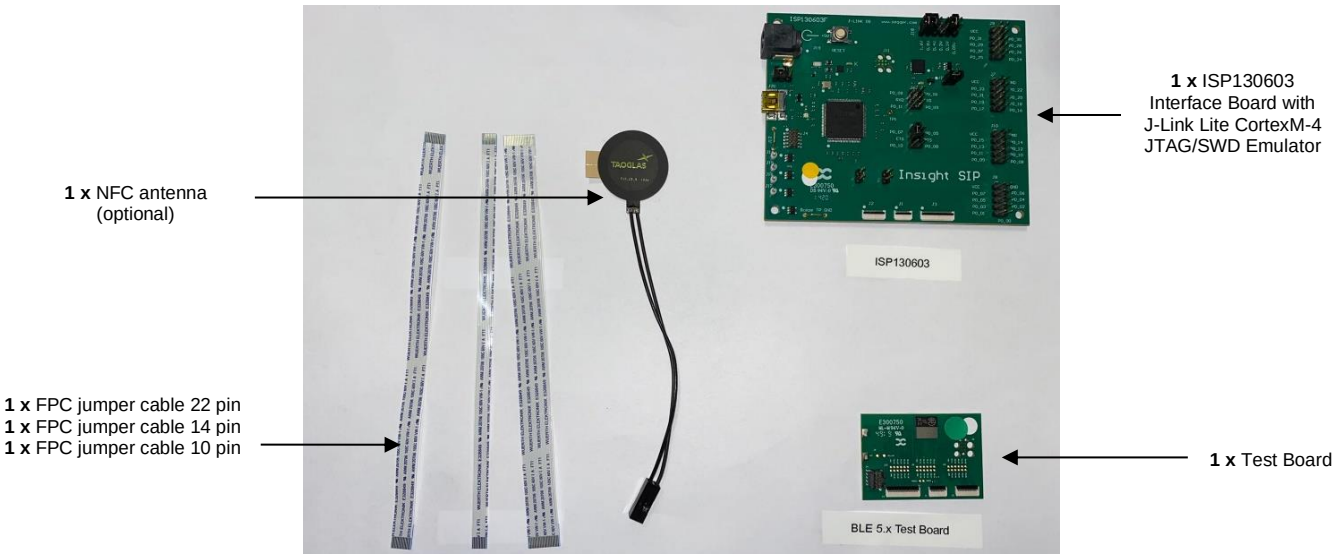
- AN201102 App Note – this document.
- BLE Module Data sheet – available on Insight SiP website.

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2. Hardware Description

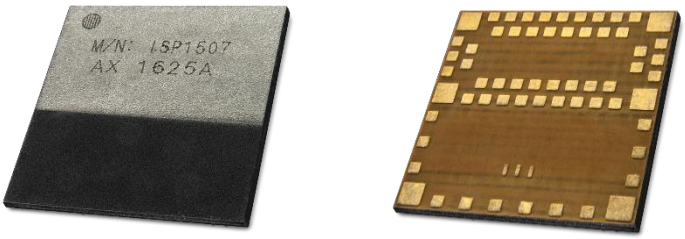
2.1. Evaluation Board Contents

This picture shows the Evaluation Board hardware content for iSP15, iSP18 and iSP19 module series:



2.2. About Insight SiP BT5 Module

ISP15, ISP18 and ISP19 module series provide a BT 5 connectivity with an embedded antenna.



They are based on Nordic Semiconductor nRF52 series 2.4 GHz wireless SoC. They integrate a 2.4 GHz transceiver, a 32bit ARM Cortex™- M4 CPU, flash memory, and analog and digital peripherals. They all support Bluetooth low energy and a range of proprietary 2.4 GHz protocols, and depending on the model, additional protocols like ANT+, Zigbee, Thread and Bluetooth Mesh.

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These modules measure 8 x 8 x 1 mm. They integrate all the decoupling capacitors, the 32 MHz and 32 kHz crystals, their load capacitors, the DC-DC converter component, the RF matching circuit and the antenna in addition to the wireless SoC. For more details, please refer to related Insight SiP module data sheet.

The following chart highlights the differences between the different modules and respective evaluation boards.

Module Type	ISP1507-AL	ISP1507-AX	ISP1807-LR	ISP1907-LL	ISP1907-HT
Chip	nRF52810	nRF52832	nRF52840	nRF52811	nRF52833
CPU	Cortex-M4 64 MHz	Cortex-M4 64 MHz & FPU	Cortex-M4 64 MHz & FPU	Cortex-M4 64 MHz	Cortex-M4 64 MHz & FPU
Flash	192 kB	512 kB	1 MB	192 kB	512 kB
RAM	24 kB	64 kB	256 kB	24 kB	128 kB
Compatible SoftDevices	S112, S113, S132	S112, S113, S132	S113, S140	S112, S113, S122, S140	S113, S122, S140

2.3. Test Board

The Test Board includes:

- The BLE module of the selected type.
- 3 x FPC connectors on top side of the board (1 x 10 pins, 1 x 14 pins and 1 x 22 pins) to access the nRF52 GPIOs and JTAG via ISP interface board.
- 2 x 5 pin header for programming and debug when connected to a Nordic Evaluation Board.
- JTAG footprint for programming and debug when connected to a Segger J-Link.

The Test Board electrical schematic is available from the website.

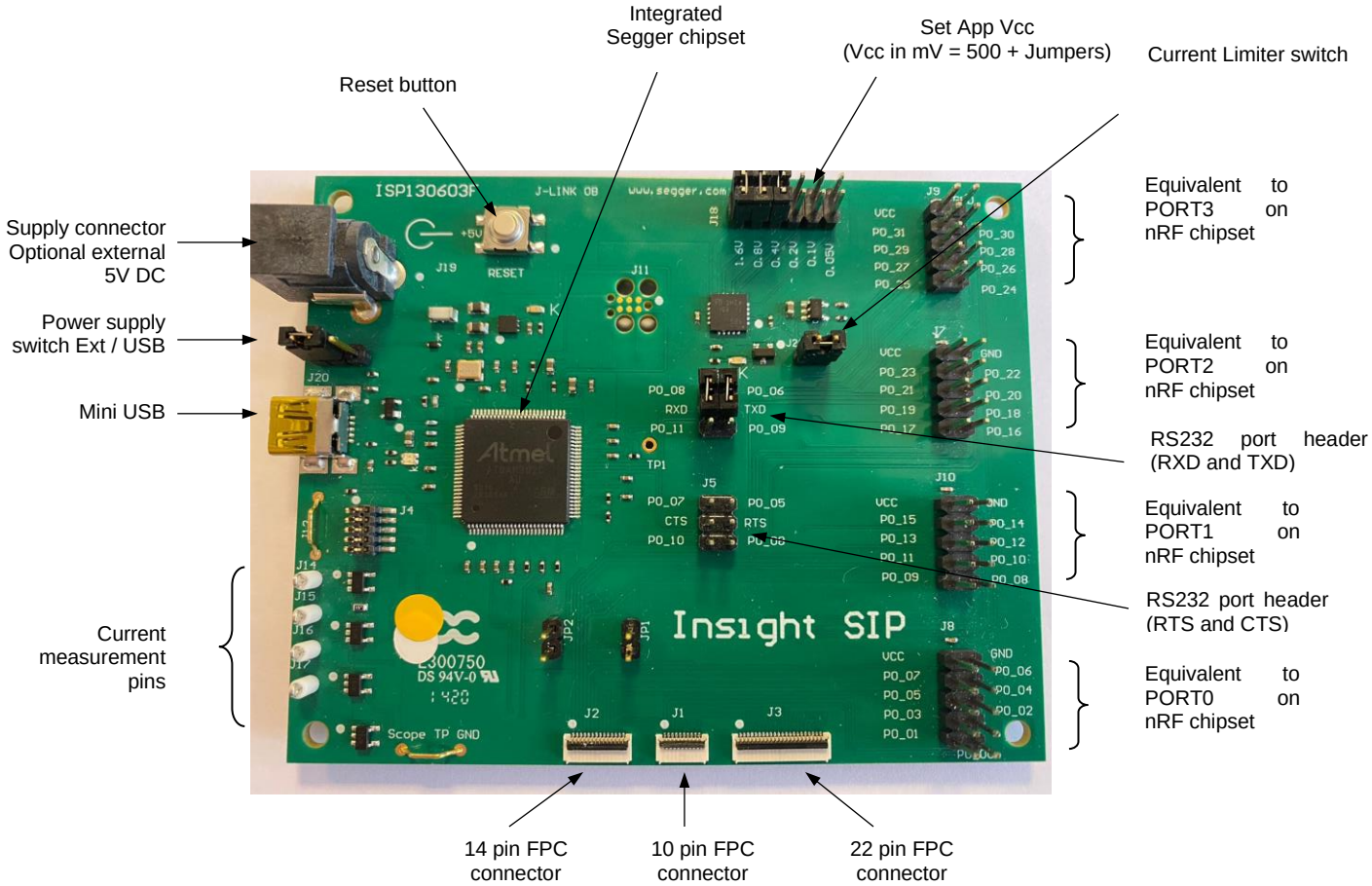


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2.4. ISP130603 Interface Board

ISP130603 is the application interface board that has dimensions of 100 x 80 mm². It provides the following features:

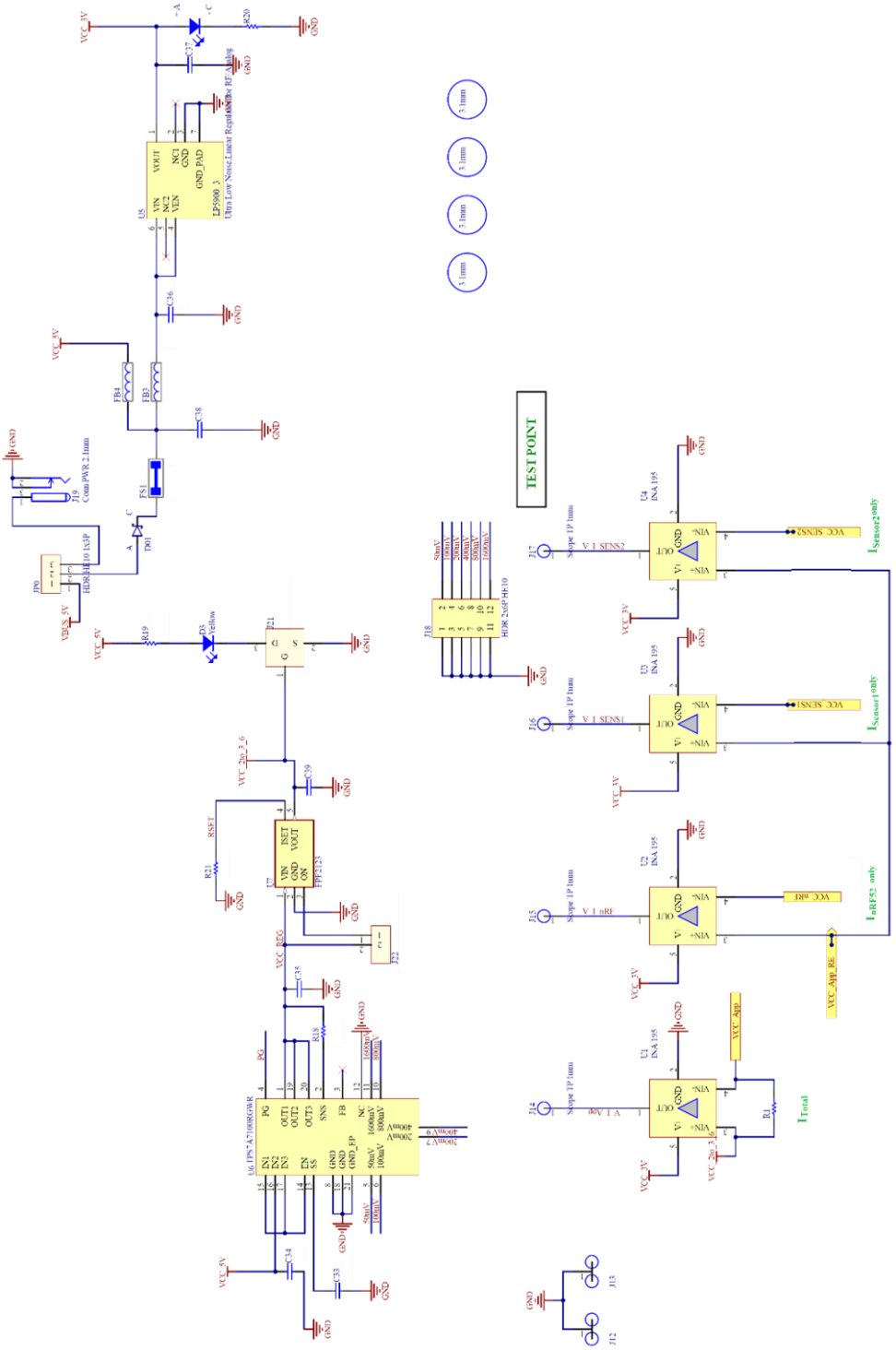
- Voltage adjustable Module Power Supply
- Segger J-Link Programming tool for all ISP modules
- Breakout headers that connect to the module GPIOs for simple prototyping of applications
- Current measurement amplifiers
- UART to PC COM Port adapter



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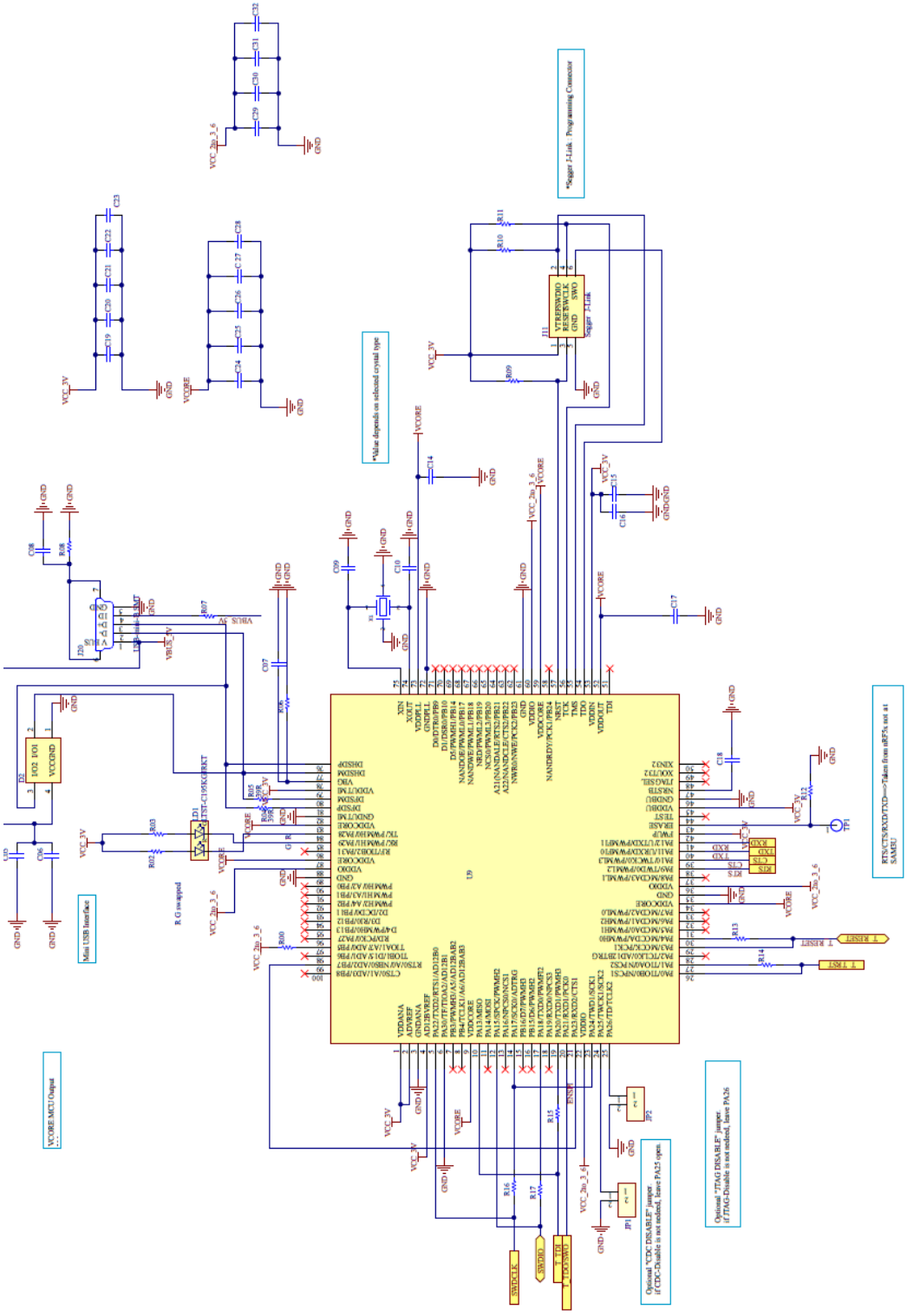
Electrical Schematic of ISP130603 Interface Board Rev F

- Power Supply



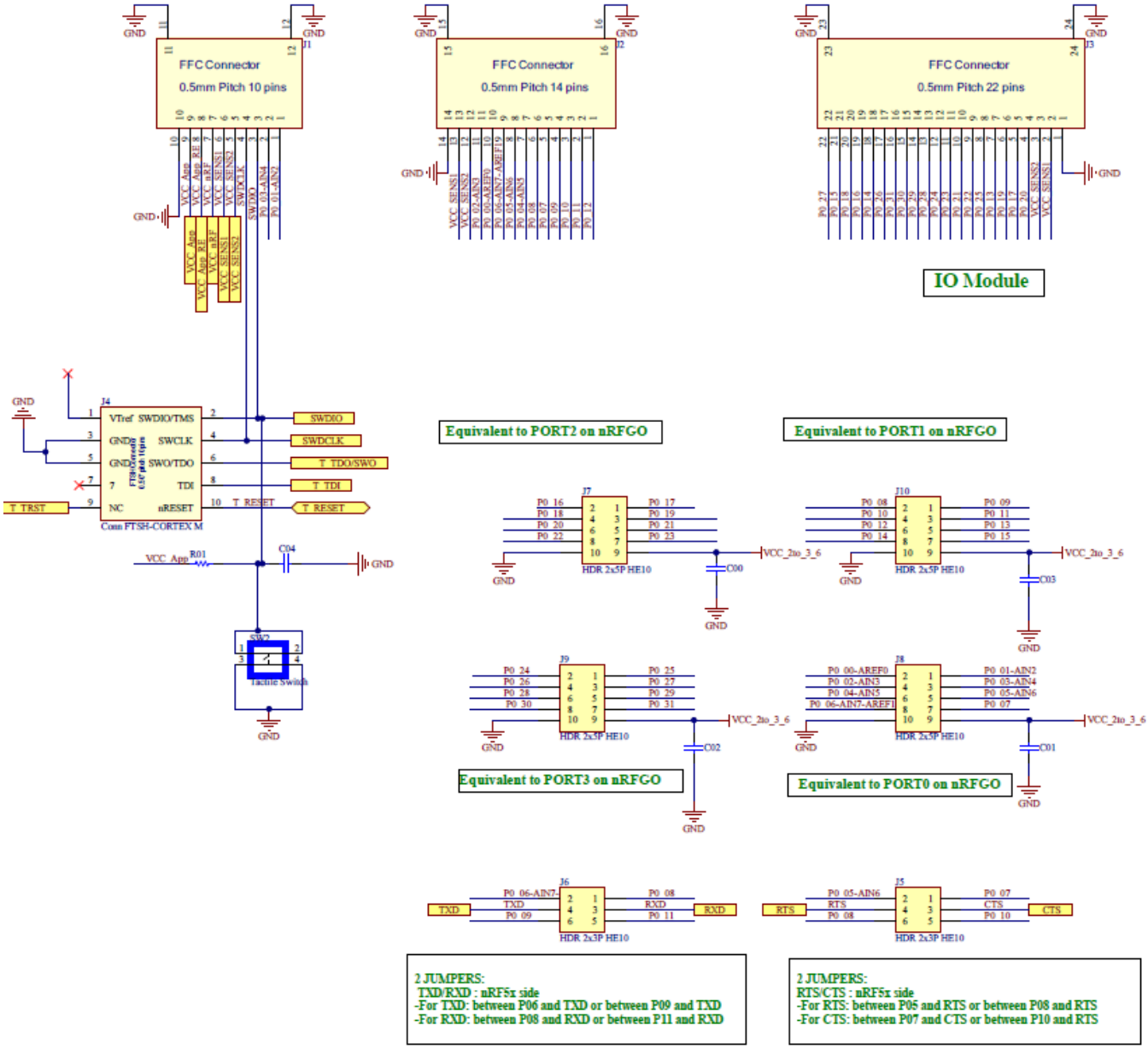
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- MCU Connections



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- Interface Board connectors



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3. Software Installation

This paragraph describes the steps to follow for software installation.

1. Download and install Segger Embedded Studio (SES) from *https://www.segger.com/downloads*. Go to *https://license.segger.com/Nordic.cgi* and fill the form. A free license key will be emailed to you, start SES, go to Tools -> License Manager and activate your license. This option allows compilation and loading of large applications.

2. Download the latest version and run the J-Link Software and documentation pack for Windows from *http://www.segger.com/jlink-software.html*.

3. Download the SDK in the following link: *https://developer.nordicsemi.com/*.

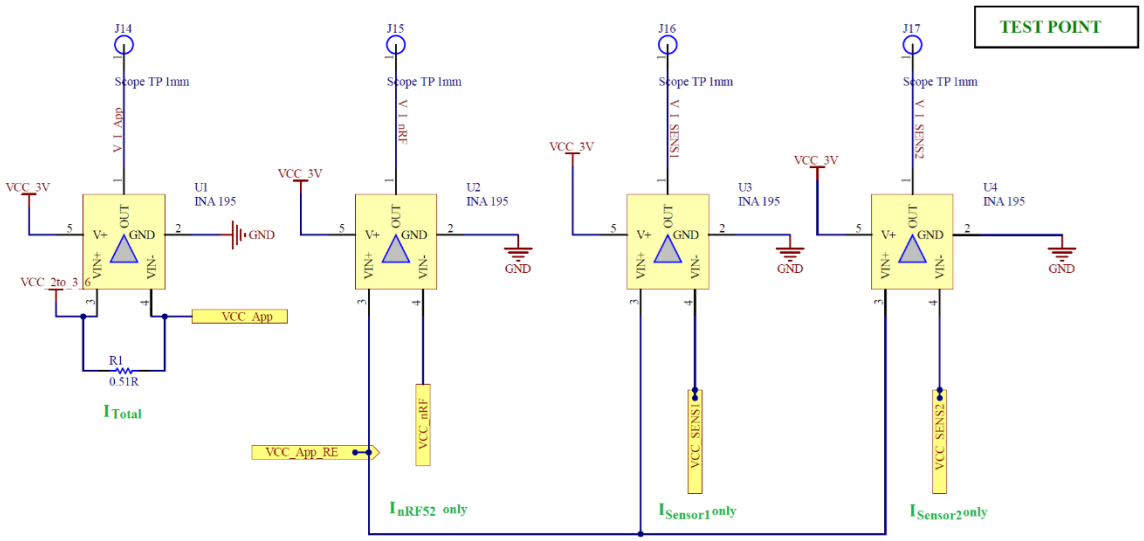
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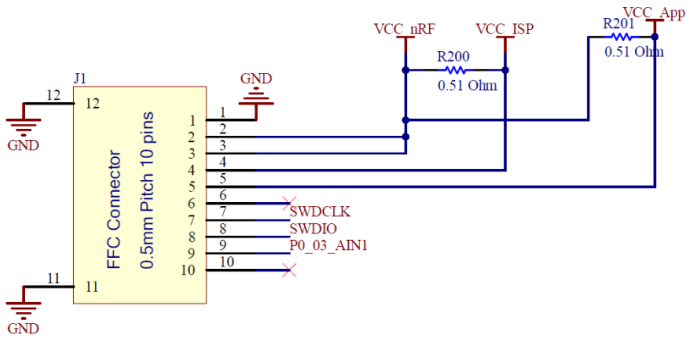
4. Current Measurement

This section describes the use of the interface board to make dynamic current measurements. To make such a current measurement on an ISP BLE module, you need the appropriate test board, an ISP130603 Interface Board, an oscilloscope, and a high impedance scope probe. The current measurement uses an INA195 OP Amplifier and resistors.

4.1. Measurement principle

Initially, refer to the appropriate test board and ISP130603 Interface board schematics. Each current measurement uses an INA195 OP Amplifier and a resistor to convert current into voltage.





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The Interface Board and the Test Board have 0.51 Ohm resistors that are used to measure current. The voltage across these resistors is fed back to the Interface Board as inputs to the INA195 Op Amp. Since the gain of the INA195 Op amplifier is 100, this is equivalent to measuring current through a 51 Ohm resistor.

- J14 gives total current that is output to the test board:

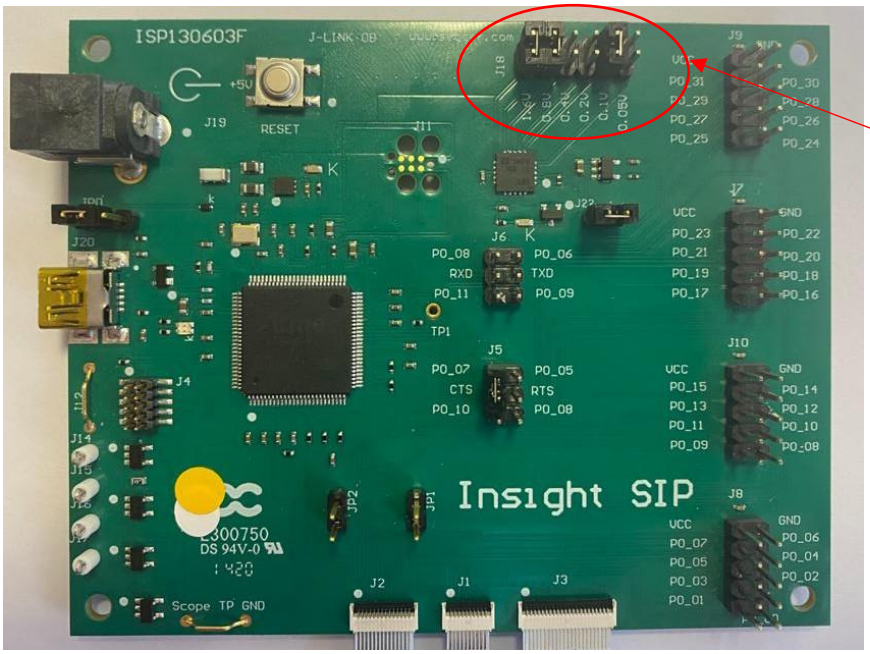
$$I_{total} = \frac{V_{j14}}{51}$$ Where V_{j14} refers to the voltage at J14.

- J15 gives the current flowing to the BLE Module.
- J16 gives the current to devices connected to Test Board via VCC APP using the 2x5 pin headers.
- J17 is not connected on the Test Boards and can be used to connect any self-designed board by the customer.

4.2. Voltage Setup

In order to adjust the voltage supply V_{out} on your interface board ISP130603, depending on voltage you need, you must connect jumpers at J18 2x6 pin header, by following the equation below:

$$V_{out} = V_{j18} + 0.5V$$ Where $0.5V$ is the reference voltage at J18.



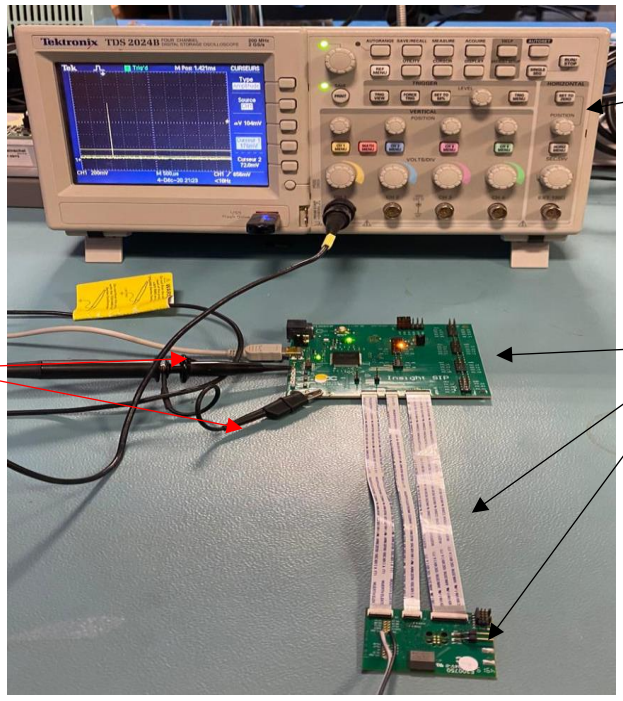
For instance, on the picture:
V_{out}
= (1.6+0.8+0.1)V + 0.5V
= 3 V

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4.3. Current Measurement Setup

1. Connect the USB cable from the Interface Board ISP130603 to your computer.
2. Connect the Test Board to the ISP130603 Interface Board with the 10 pin, 14 pin and 22 pin FPC jumper cables (0.5 mm pitch, provided in the Development Kit).
3. Connect the oscilloscope to scope probe.
4. Depending on which current you need to measure connect the scope probe to any of test point J14 / J15 / J16 on the ISP130603 Interface board.

Test point	Current measurement
J14	Total current
J15	Current on ISP Module
J16	Current on devices connected to VCC_APP



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4.4. Firmware example for Current measurement during BLE Transmit/Receive pulses

The BLE Proximity application is used in this example:

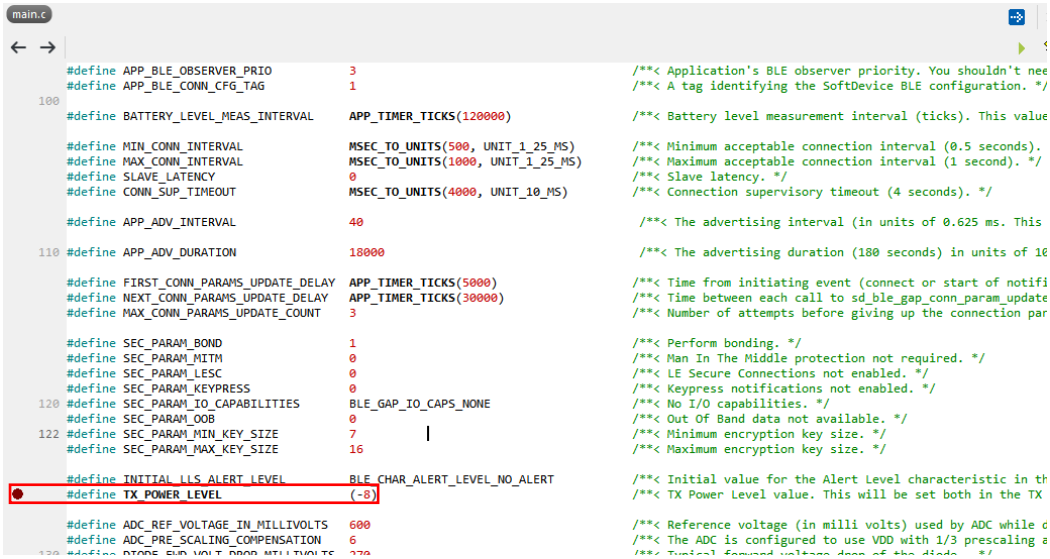
1. Start SEGGER Embedded Studio.

2. Select File then Click on “Open Solution”. Select the appropriate BLE Proximity application from the SDK for the specific module you are using. Refer to the table below:

Module Type	ISP1507-AL	ISP1507-AX	ISP1807-LR	ISP1907-LL	ISP1907-HT
Compatible SoftDevices	S112, S113, S132	S112, S113, S132	S113, S140	S112, S113, S122, S140	S113, S122, S140
Nordic Board	PCA10040e	PCA10040	PCA10056	PCA10056e	PCA10100

   The appropriate example is the one using the correct board definition for the module and the correct soft device. For example, an ISP1507-AX with an S132 softdevice load the application at the following location:
   …\nRF5_SDK_17.0.2_d674dde\examples\ble_peripheral\ble_app_proximity\pca10040\s132\ses\ble_app_proximity_pca10040_s132.emProject

3. In the Main.c file adjust the TX power using TX_Power_Level as shown below:



4. Add the following line to the code” *sd_power_dcdc_mode_set(NRF_POWER_DCDC_ENABLE);* “ to activate the DCDC as shown below:

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5. Click Build Target and Download.

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5. Example with ISP1507-AX Test Board

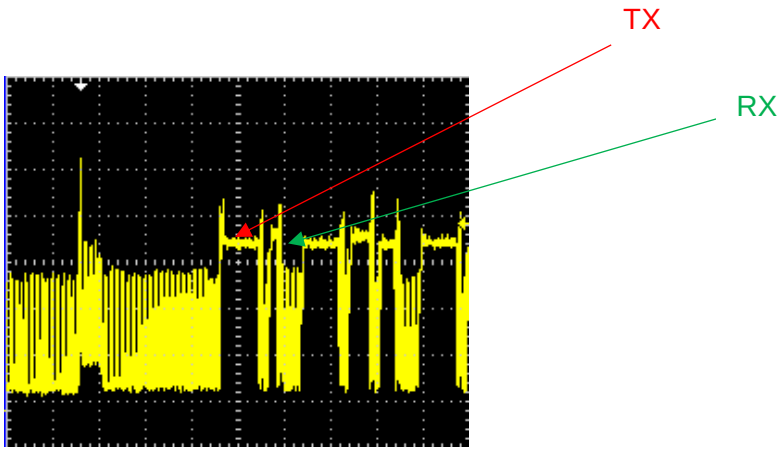
This example uses an ISP1507-AX-TB for the current measurement. The supply voltage to the module is set to 3V using the jumpers on the interface board. The DCDC is either enabled or disabled using the above line of code.

5.1. Total Current

The scope probe is connected to J14 on ISP130603 Interface Board.

The INA195 has a DC offset when measuring zero voltage. To remove the effect of this offset it is assumed that the BLE device has virtually zero current (few uA) in between Tx Rx bursts when it is in sleep mode.

The result is shown below:



In this part the Transmitter Peak Current is measured, with DCDC enabled I_{total} = 6mA

To deactivate the DCDC "//" is used to deactivate the line of code:

```
int main(void)
{
    bool erase_bonds;

    // Initialize.
    log_init();
    timers_init();
    buttons_leds_init(&erase_bonds);
    power_management_init();
    ble_stack_init();

    //  sd_power_dcdc_mode_set(NRF_POWER_DCDC_ENABLE);

    adc_configure();
    gap_params_init();
    gatt_init();
    advertising_init();
    db_discovery_init();
    services_init();
    conn_params_init();
    peer_manager_init();

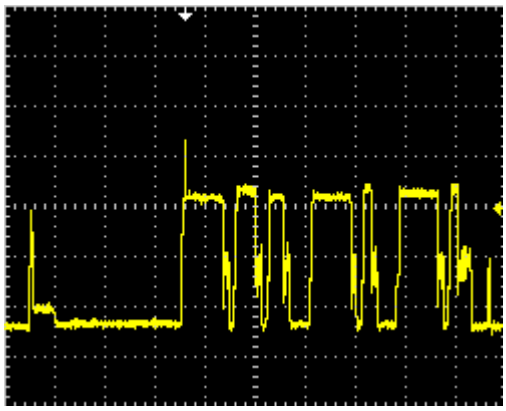
    // Start execution.
    NRF_LOG_INFO("Proximity example started.");
    advertising_start(erase_bonds);
    tx_power_set();

    // Enter main loop.
    for (;;)
    {
        idle_state_handle();
    }
}

/**
 * @}
 */
```


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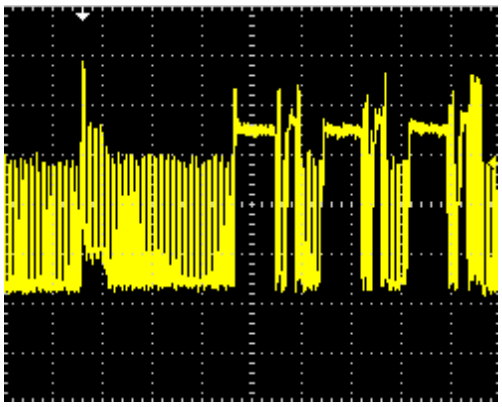
The measurement obtained is shown below:



Transmitter Peak Current I_{total} = 9.9mA without DCDC.

5.2. Current On ISP1507-AX

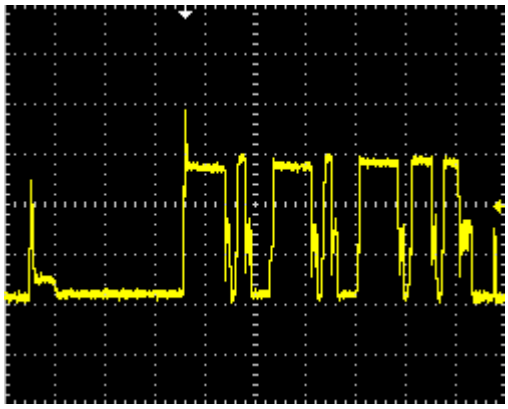
The voltage probe is connected to J15 on ISP130603 Interface Board; the result is shown below:



Peak Receiver Current with DCDC enabled I_{total} = 6mA

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Without DCDC, the result is shown below:

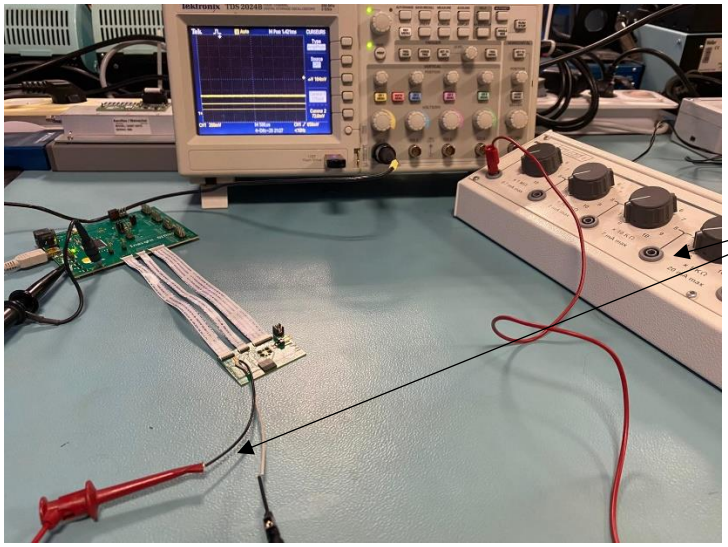


I_{total} = 9.9 mA Peak Receiver Current without DCDC.

There is no change between the current flowing to ISP1507-AX and the total current since there is no current drawn by Vcc_App.

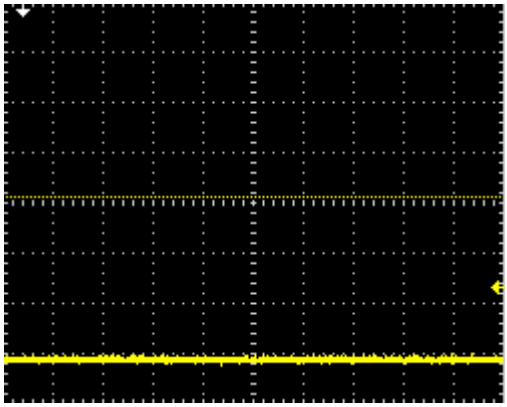
5.3. Current on device connected to VCC_APP

The voltage probe is connected to J16 on ISP130603 Interface Board, a variable resistor is added between VCC_APP and GND as shown in the image below as an example of the current flowing to a device connected to VCC_APP.

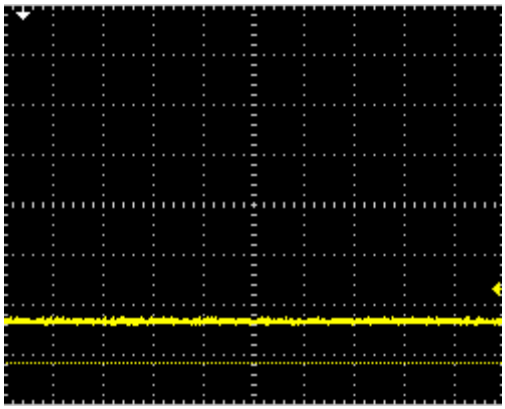


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To calibrate for zero current in VccApp the variable resistor is set to 1 MOhm. A cursor can be used to fix the zero-current level on the scope.



When the variable resistor is set to 1 kOhm the result is as shown below:



The offset between the “zero current” cursor and the actual current is used to determine the current flowing in Vcc App. In this case 3. mA. (3V / 1 kOhm)

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