TDK InvenSense EPCOS tronics microsystems MICRONAS icsense THE IC DESIGN COMPANY

SmartMotion® Platform

TDK InvenSense Development Tool for Motion Sensors

Agenda

- SmartMotion Platform
  - 6 Axis, 7-Axis and 9-Axis development kits
    - DK-20602, DK-20648, DK-20789, DK-20948
- SmartMotion Hardware Overview
  - Sensor specifications
  - Board layout and Connectors
  - Bring up the board
  - Purchasing the SmartMotion Platform
- SmartMotion Software
  - MotionLink
  - Embedded Motion Drivers (eMD)
  - External Sensor Connection
  - eMD Porting Guidelines

The SmartMotion Platform

SDC - October 2017

What is a Good development platform ?

- Accelerates development of end products for faster market deployment
- “Out of the box” experience for quick set-up
  - Single board design, simple connection
  - Software included, easy to use collateral
  - No support required to bring up the platform
- Affordable; buy several platforms for parallel development
- Debugging features to assist in code development
- System prototyping and demonstration vehicle
- Ability to develop applications without actual hardware to expedite product delivery

TDK InvenSense SmartMotion® Platform

User Friendly Development Platform for InvenSense 6-Axis, 7Axis and 9-Axis Motion Sensors

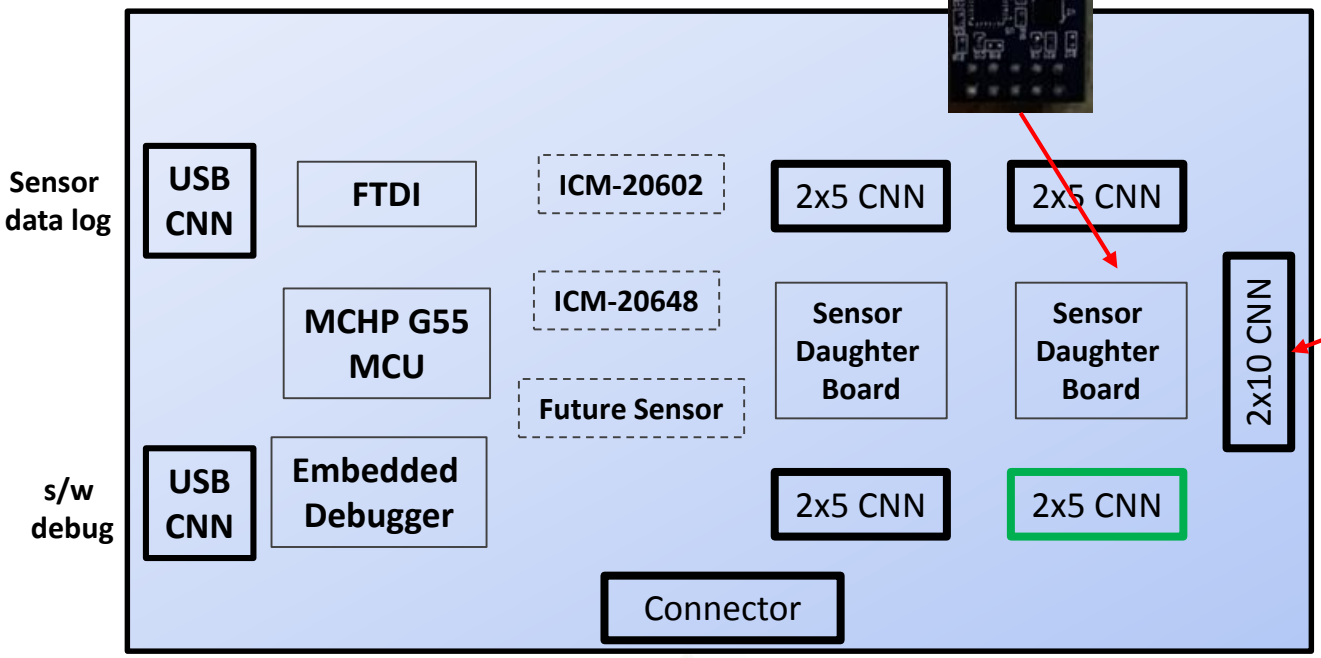
https://www.invensense.com/smartmotion-platform/

SmartMotion® Platform

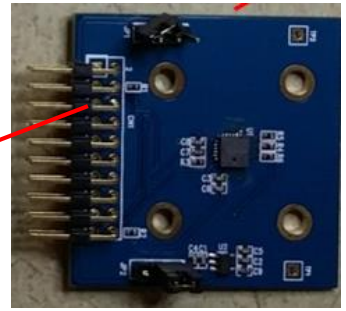
- Single Board “Out of the Box” experience
  - Microchip G55 MCU + TDK InvenSense Motion Sensor
- On-board embedded debugger
  - Saves $100-$150 for external debugger
  - Simpler set up/no cables for debugger
  - Program and debug the MCU
- Affordable - $99 ASP
- Better than other Sensor Development Kits
- Scalable design
  - Supports legacy and future motion sensors
  - WiFi/BLE support with external modules from Microchip
- Less than 10 minutes to set-up

Version 1 - 6 Axis Sensors

Sensor
Daughter Board

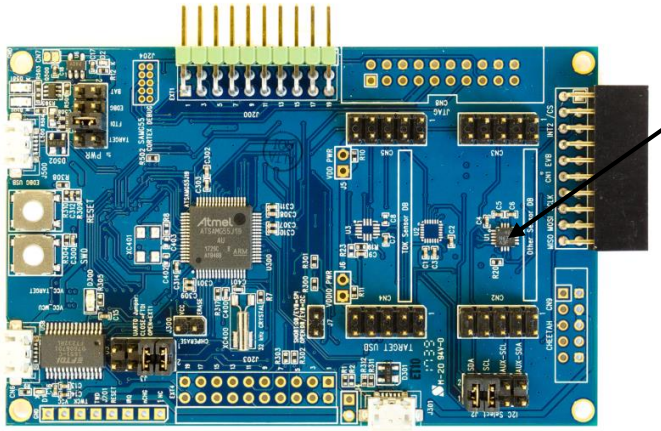


InvenSense
Sensor EVB



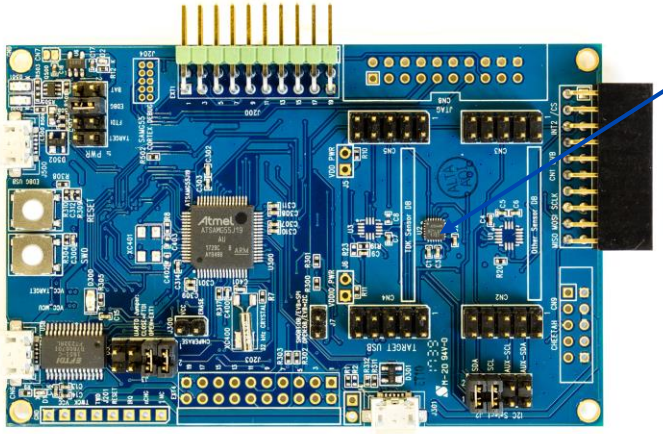
Microchip
WiFI/BLE Module

SmartMotion® 6-axis Platforms



ICM-20602

DK-20602



ICM-20648

DK-20648

Version 2 – 7 and 9 axis Sensors

Sensor
Daughter Board

Sensor data log

USB CNN

FTDI

ICM-20789

2x5 CNN

2x5 CNN

ICM-20948

MCHP G55 MCU

Sensor Daughter Board

Sensor Daughter Board

Future Sensor

2x10 CNN

s/w debug

USB CNN

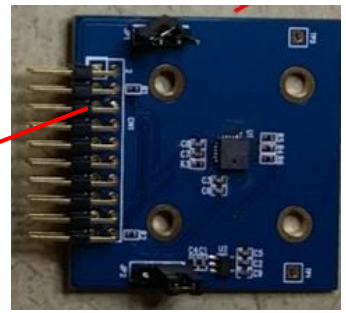
Embedded Debugger

2x5 CNN

2x5 CNN

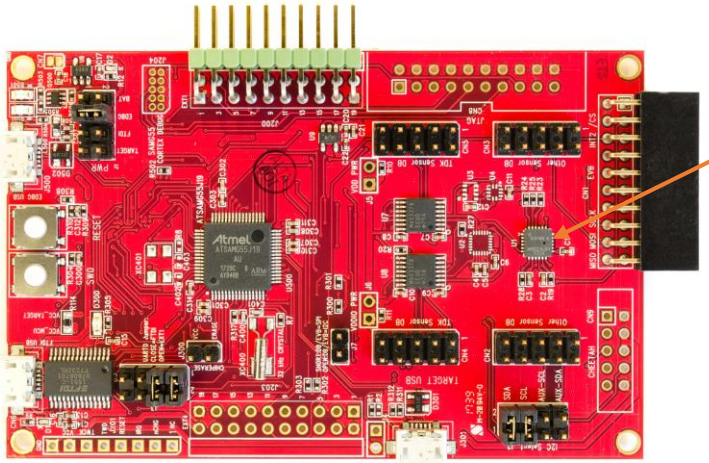
Connector

InvenSense
Sensor EVB



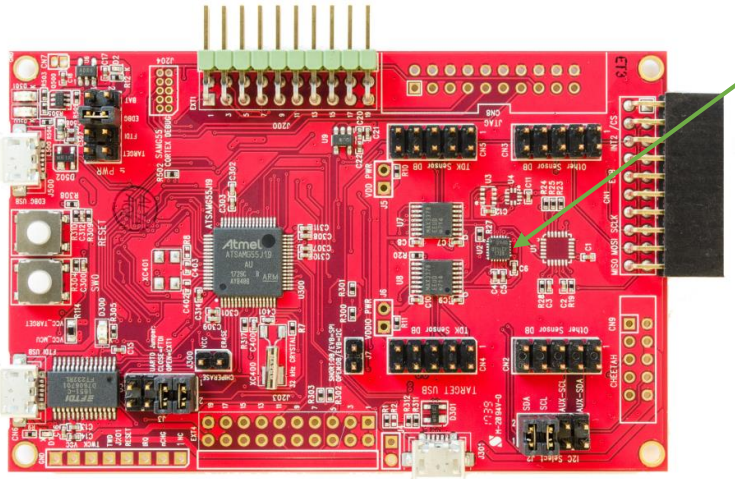
Microchip
WiFI/BLE Module

SmartMotion® 7, 9-axis Platforms



ICM-20789

DK-20789



ICM-20948

DK-20948

What is a Good development platform ?

- Accelerates development of end products for faster market deployment
- “Out of the box” experience for quick set-up
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TDK InvenSense SmartMotion® Platform

User Friendly Development Platform for InvenSense 6-Axis, 7Axis and 9-Axis Motion Sensors

https://www.invensense.com/smartmotion-platform/

SmartMotion : Hardware and Selection

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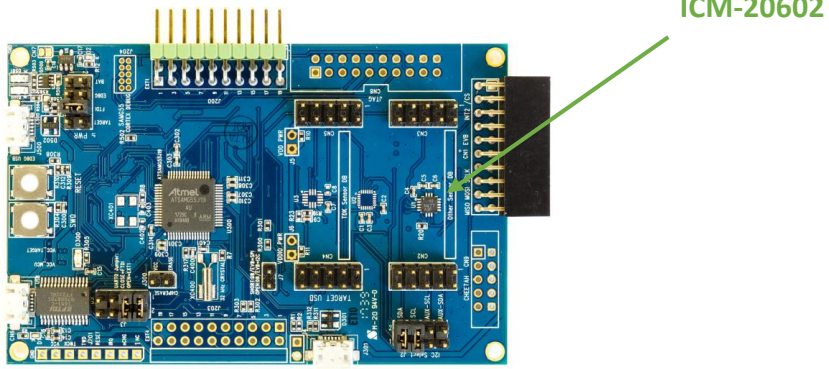
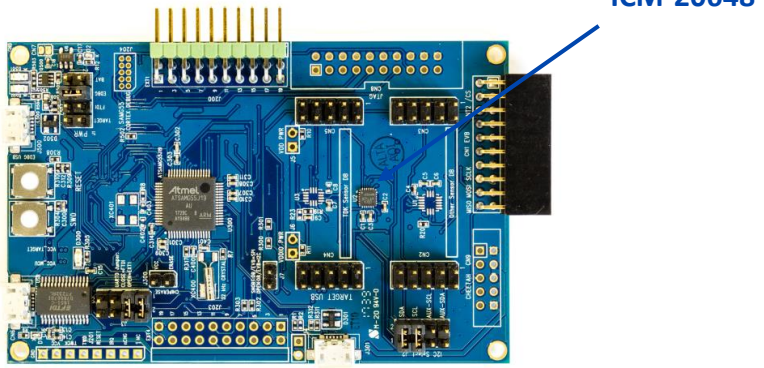
SmartMotion Platforms

SmartMotion™ Platform – 6 Axis

DK-20602

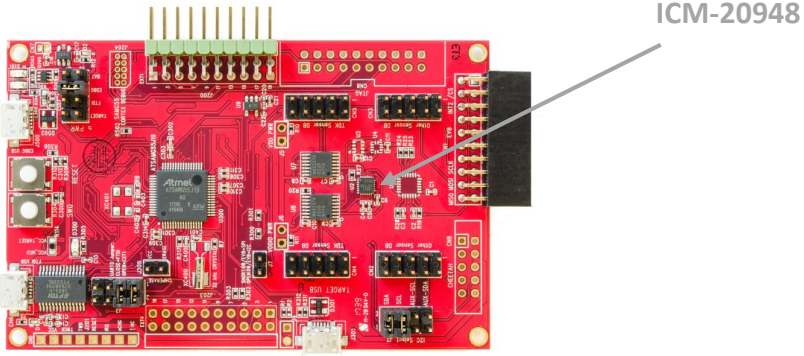


DK-20648

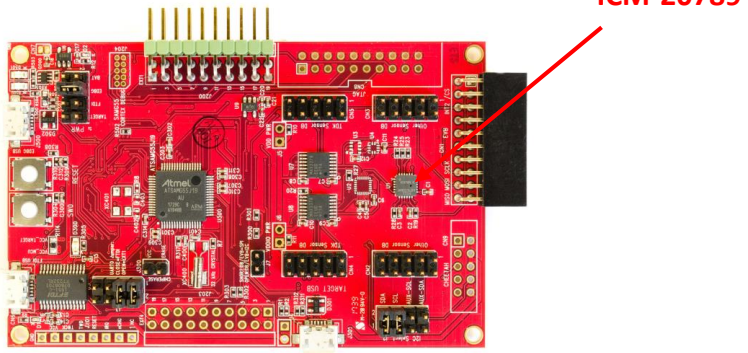


SmartMotion™ Platform – 7 and 9 Axis

DK-20948



DK-20789



SmartMotion : 6 Axis Platforms

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DK-20602 Motion Sensor

ICM-20602

World's Best 6-axis Solution

Samples: Now
Production: Now

Specifications

- High Performance Gyro
  - Gyro Sensitivity Error: ±1%
  - Gyroscope Noise: ±4mdps/√Hz
- High Performance Accel
  - Accel Noise: ±100µg/√Hz
  - Accel Sensitivity: ± 1%
- Low Power Solution
  - Full Power: 2.79mA
  - LP Gyro/Accel Mode: 1.33mA
- Gyroscope Full-Scale Range: ±250/500/1000/2000 deg/sec
- Accelerometer Full-Scale Range: ±2/4/8/16g
- Package Size: 3x3x0.75mm 16-Pin LGA
- Software Available: Yes

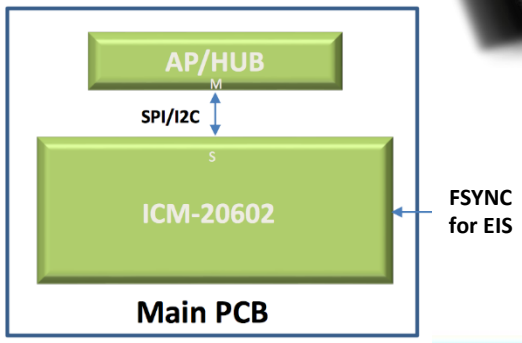
Datasheet: ICM-20602 DataSheet

Applications

- IoT
- Augmented Reality
- Drone
- Virtual Reality

Solution Benefits

- Device includes 1K-byte FIFO to reduce traffic on serial bus interface
- Reduce power consumption by allowing the system processor to burst read sensor data and then go to LP mode
- Includes on chip, 16-bit ADC's, programmable digital filters, an embedded temp sensor, and programmable interrupts.



DK-20648 Motion Sensor

ICM-20648

6-Axis DMP Enabled Solution

Samples: Now
Production: Now

Specifications

- Digital Motion Processor (DMP) for autonomous operation
- Programmable interrupts, filters, and 4k-byte FIFO
- Gyroscope Full-Scale Range: ±250/500/1000/2000 deg/sec
- Accelerometer Full-Scale Range: ±2/4/8/16g
- Runtime Calibration
- Operating Temperature Range: -40ºC to 85ºC
- Operating Voltage Range:
  - VDD 1.71V – 3.6V
  - VDDIO: 1.71V – 3.6V
- Host Interface: SPI 7MHz, I²C up to 400kHz
- Package Size: 3x3x0.9mm 24-Pin QFN
- Software Available: Yes

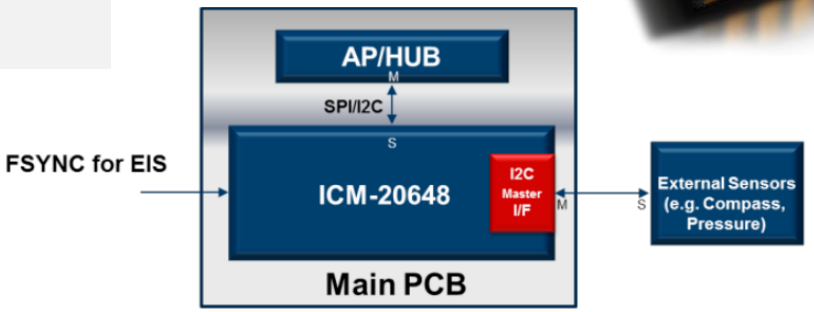
Datasheet: ICM-20648 DataSheet

Applications

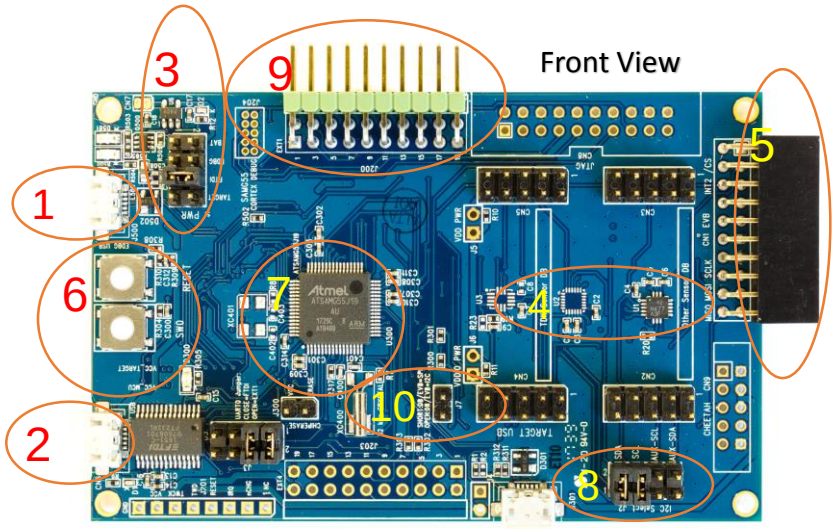
- IoT
- EIS
- Wearables

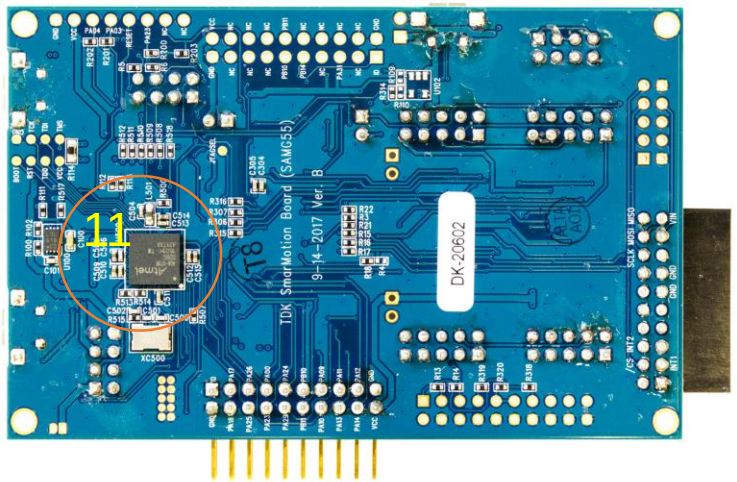
Solution Benefits

- Provides Step Count, Activity Classifier, and B2S (Bring-to-See) Gestures tuned for wrist worn wearable applications.
- DMP offloads computation of motion processing algorithms from the host processor, improving system power performance
- Enhanced FSYNC functionality to improve timing for applications like EIS



SmartMotion Platform – 6 Axis





Main Hardware Features

1. EDBG USB – Embedded Debugger USB output and/or power input
2. FTDI USB – Main UART output for software. Default power input for SmartMotion board
3. PWR Source Select – Can be configure to select power from different sources. By default it is set for FTDI input (5+6)
4. On-Board Motion Sensor – U1 footprint for ICM-20602. U2 for ICM-20648
5. TDK Sensor EVB Connector – Connector to attached other TDK-InvenSense Sensor EVB boards. Can only support 2.5V and above!
6. Reset and User Button – Reset used for SAMG55 MCU, User Button optional for software use
7. ATMEL SAMG55 MCU – ARM Cortex-M4 MCU, http://www.microchip.com/wwwproducts/en/ATSAMG55
8. Sensor I2C Selection – selects sensor I2C slave source from primary I2C or AUX I2C. Default is primary (1+2, 3+4)
9. Extension Header – for future support of other components such as BLE. Same header as Microchip's Xplained-Pro Board.
10. External EVB interface – jumper to select I2C (open) or SPI (closed) interface to the external EVB if attached
11. Embedded Debugger – for flashing main MCU and code tracing. No external JTAG needed!

SmartMotion : 7 and 9 Axis Platforms

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DK-20789 Motion Sensor

ICM-20789

World's Only 7-axis Integrated Solution

Samples: Now
Production: Now

Specifications

- Programmable interrupts, filters, and 4k-byte FIFO
- Gyroscope Full-Scale Range: ±250/500/1000/2000 deg/sec
- Accelerometer Full-Scale Range: ±2/4/8/16g
- Pressure Operating Range: 300hPa – 1100hPa
- Relative Pressure Accuracy: **±1Pa (**10hPa change,700-1000hPa)
- Absolute Pressure Accuracy: ±1hPa(300hPa-1100hPa,0ºC-65ºC)
- Temperature Sensor Accuracy: ±0.4ºC
- Operating Temperature Range: -40ºC to 85ºC
- Operating Voltage Range:
  - VDD 1.7V – 3.45V
  - VDDIO: 1.8V
- Host Interface: SPI 8MHz, I^2C up to 400kHz
- Packages: 4 x 4 x 1.365mm 24-pin LGA

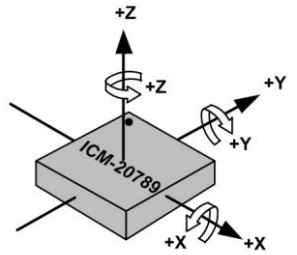
Product Brief:

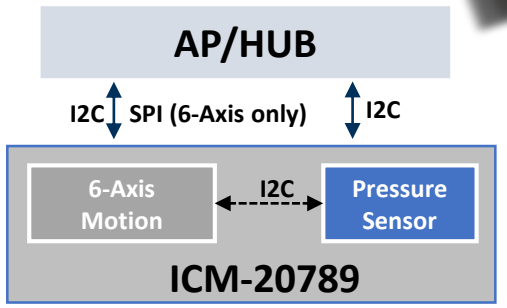
Applications

- Drones
- Motion-based controllers
- Mobile Phones
- Virtual Reality Headsets/Controllers
- Toys

Solution Benefits

- Integrated & calibrated Accel+Gryo+Pressure+Temp sensor provides quick time-to-market in small footprint
- Allow host to sleep/save power while monitoring motion
- Detect Z-height of 8cm for accurate motion measurements: navigation, dead-reckoning, floor detection, fitness recognition
- Lower power consumption extends battery life
- Easy migration from 6-Axis motion sensor to 6-Axis+Pressure





DK-20948 Motion Sensor

ICM-20948

World's Best 9-axis Integrated Solution

Samples: Now
Production: Now

Specifications

- Digital Motion Processor (DMP) for autonomous operation
- Gyroscope Full-Scale Range: ±250/500/1000/2000 deg/sec
- Accelerometer Full-Scale Range: ±2/4/8/16g
- Operating Voltage Range:
  - VDD 1.71V – 3.6V
  - VDDIO: 1.71V – 1.95V
- Host Interface: SPI 7MHz, I^2C up to 400kHz
- Software Available: Yes
- Low Power Mode: 2.5mW
- Compass FSR: ± 4900µT
- Package Size: 3x3x.1mm 24-Pin QFN
- Software Available: Yes

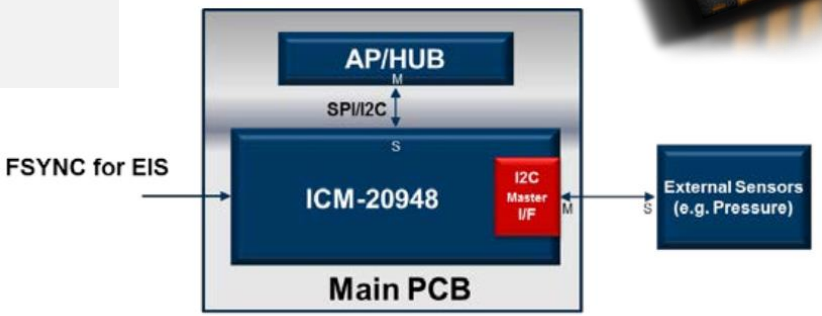
Datasheet: ICM-20948 DataSheet

Applications

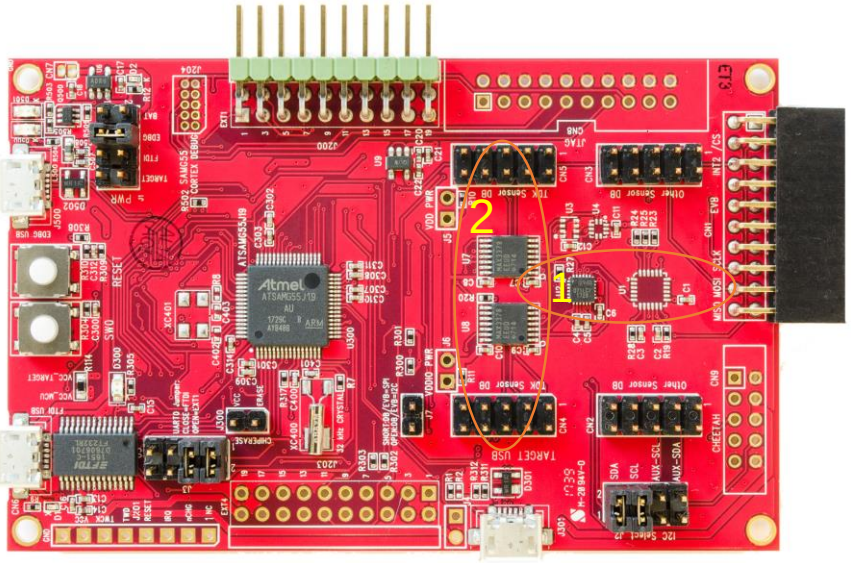
- IoT
- Wearable
- Drone

Solution Benefits

- Lowest power 9-axis solution in the world
- P2P compatible with the MPU-9250
  - 1/3 less power then previous solution
- Supports FSYNC for EIS



SmartMotion Platform : 7 and 9 Axis



Main Hardware Features

Similar to 6 Axis Board except for the following

1. On-Board Motion Sensor – U2 footprint for ICM-20948, U1 footprint for ICM-20789
2. Level Shifter – change power level to 1.8V for the on-board sensor only. This is primary for ICM-20948 and ICM-20789 which requires this voltage.

Purchasing a SmartMotion Platform

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SmartMotion Platform

The various SmartMotions are all easily purchasable on the following TDK authorized distributors for $99 USD

Distribution	URL
DigiKey	https://www.digikey.com/products/en?keywords=DK-20602 https://www.digikey.com/products/en?keywords=DK-20648 https://www.digikey.com/products/en?keywords=DK-20789 https://www.digikey.com/products/en?keywords=DK-20948
Mouser	https://www.mouser.com/ProductDetail/TDK/DK-20602/ https://www.mouser.com/ProductDetail/TDK/DK-20648/ https://www.mouser.com/ProductDetail/TDK/DK-20789/ https://www.mouser.com/ProductDetail/TDK/DK-20948/
AVNET	https://www.avnet.com/wps/portal/us/
CDI	https://www.cdiweb.com/ProductDetail/DK20602-TDK-InvenSense/613431/ https://www.cdiweb.com/ProductDetail/DK20648-TDK-InvenSense/613432/ https://www.cdiweb.com/ProductDetail/DK20789-TDK-InvenSense/613975/ https://www.cdiweb.com/ProductDetail/DK20948-TDK-InvenSense/613433/

Individual TDK-InvenSense Motion EVBs are also widely available at same distributors

SmartMotion Platform Contents

Each purchased SmartMotion comes with the following

Contents	Description
Protective Packaging	The SmartMotion Platform come in a sturdy easy to carry box with protective foam. Please reference MEMS Handling Guide on how to prevent damage to MEMS sensors.
SmartMotion Platform	The SmartMotion board comes with the default jumper settings. It also comes with the latest MotionLink Software Tool pre-flashed into the MCU.
QuickStart Guide	Short description on SmartMotion overview and how to quickly get started along with links to downloadable software.

Connecting the SmartMotion Platform

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It’s so Simple!

- Connecting the Boards
  - PC/Laptop – preferably running Win 7
  - Micro-USB cables –
    - FTDI USB Connector (CN6) to PC – Required for default power and output
    - EDGB USB Connector (J500) to PC – Optional, only needed if customers planning to flash or trace code. For eMD can be used for debug message outputs.

SmartMotion : Software Tools

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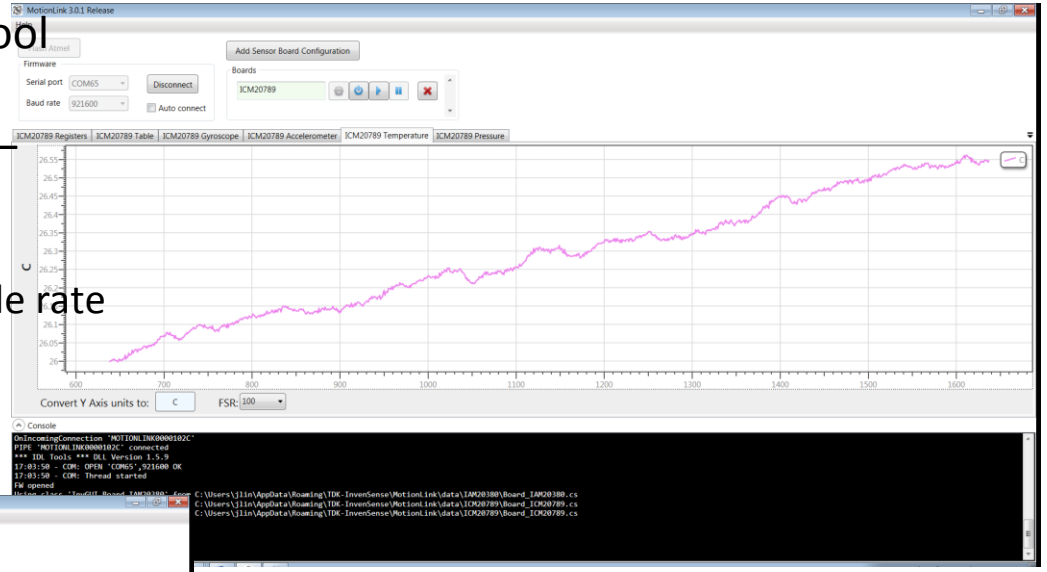
Software Evaluation Tools

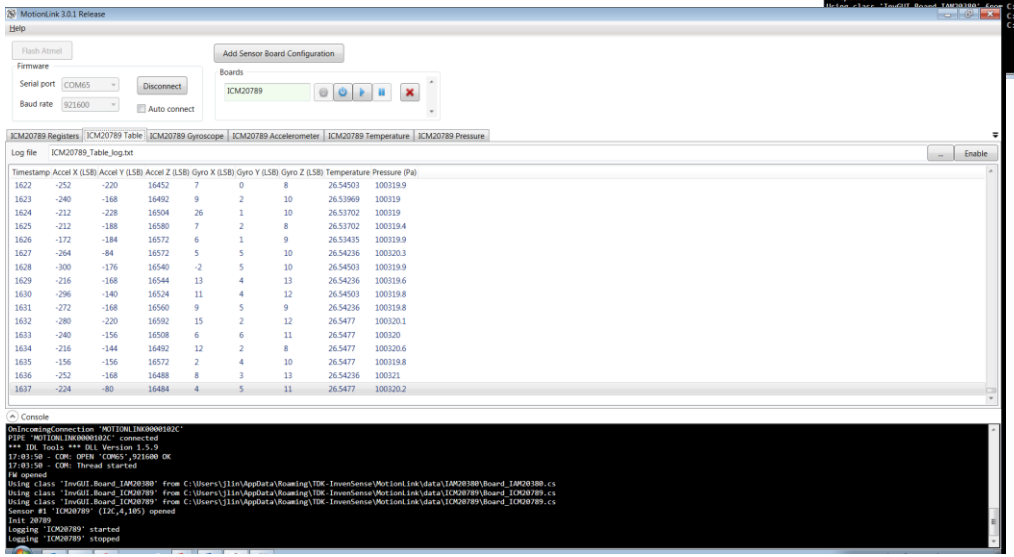
- 2 Software Packages
  - SmartMotion Installer with MotionLink
  - Embedded Motion Drivers (eMDs)
  - Both tools available for free download at the TDK-InvenSense Developer's Corner (requires registration)

https://www.invensense.com/developers/software-downloads/

Software Evaluation Tools

The MotionLink - Hardware Evaluation Tool





- PC Based Software with following features –
  - ¬ Read Register Map Values
  - ¬ Simple I2C read and writes
  - ¬ Display raw sensor data up to 1Khz sample rate
  - ¬ Log Data to text file
  - ¬ Display graphical sensor data

- Why MotionLink? –
  - ¬ Evaluate and log raw gyro, accel, and other sensor data
  - ¬ Will support all channel motion parts

Software Evaluation Tools

MotionLink supports the latest TDK-InvenSense Motion Hardware including

TDK Part Number	URL
MPU-6000	https://www.invensense.com/products/motion-tracking/6-axis/mpu-6050/
ICM-20601	https://www.invensense.com/products/motion-tracking/6-axis/icm-20601/
ICM-20602	https://www.invensense.com/products/motion-tracking/6-axis/icm-20602/
ICM-20608-G	https://www.invensense.com/products/motion-tracking/6-axis/icm-20608-2/
ICM-20648	https://www.invensense.com/products/motion-tracking/6-axis/icm-20648/
ICM-20649	https://www.invensense.com/products/motion-tracking/6-axis/icm-20649/
ICM-20789	https://www.invensense.com/products/motion-tracking/7-axis/
ICM-20948	https://www.invensense.com/products/motion-tracking/9-axis/icm-20948/
IAM-20680	https://www.invensense.com/products/motion-tracking/6-axis/iam-20680/
ICG-20660L	https://www.invensense.com/products/motion-tracking/6-axis/icm-20660/

Software Evaluation Tools

The Embedded Motion Driver (eMD) for SmartMotion Platforms

- Fully Featured Motion Software including
  - ¬ Sensor Fusion
  - ¬ Gesture Tracking
  - ¬ DMP Image (if applicable)
  - ¬ Factory Test and Calibration
  - ¬ In-Use Calibration

- Currently supported SmartMotion eMDs
  - ¬ ICM20602
  - ¬ ICM20648
  - ¬ ICM20948
  - ¬ ICM20789

Software Evaluation Tools

ICM-20948 eMD Features Example -

- Raw Accelerometer
- Raw Gyroscope
- Raw Magnetometer
- Dynamically Calibrated Accelerometer
- Dynamically Calibrated Gyroscope
- Dynamically Calibrated Magnetometer
- Game Rotation Vector – Accel and Gyro based RV
- Rotation Vector – Accel, Gyro, and Mag based RV
- Geomagnetic Rotation Vector – Accel and Mag based RV
- BAC (Basic Activity Classifier) – Android-based activity detection of Walking, Standing, Running, Biking, and Transport
- Step Detector
- Step Counter (Pedometer)
- SMD (Significant Motion Detection)
- PickUp Detection
- Tilt Detection
- Gravity
- Linear acceleration
- Orientation
- B2S (Bring to See) Detection
- Heading
- Euler Angles
- Quaternion generation

MotionLink : Getting Started

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Installing the PC Software

3rd Party Software Drivers –

- ATMEL Studios – free Atmel IDE for all Microchip/Atmel MCUs
  - ¬ Required to flash and trace code
  - ¬ As of release MotionLink and eMD developed using Atmel Studio v. 7.0.1417
  - ¬ http://www.atmel.com/microsite/atmel-studio/

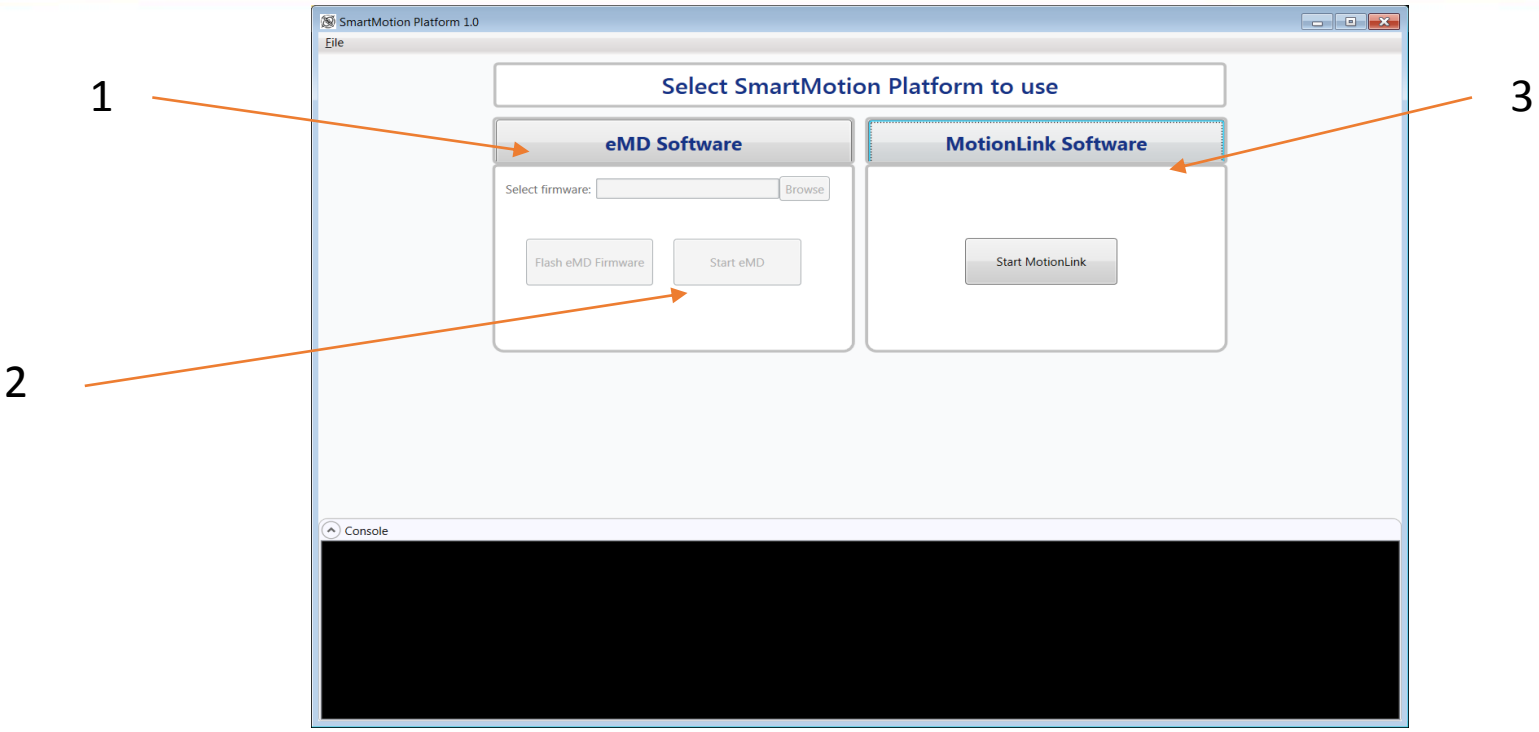
- FTDI Driver - http://www.ftdichip.com/Drivers/VCP.htm

Install SmartMotion Installer with MotionLink–

- Download and Install from InvenSense Developer's Corner –
  - ¬ https://www.invensense.com/developers/software-downloads/

Connect SmartMotion platform and open MotionLink at Launcher!

SmartMotion Launcher

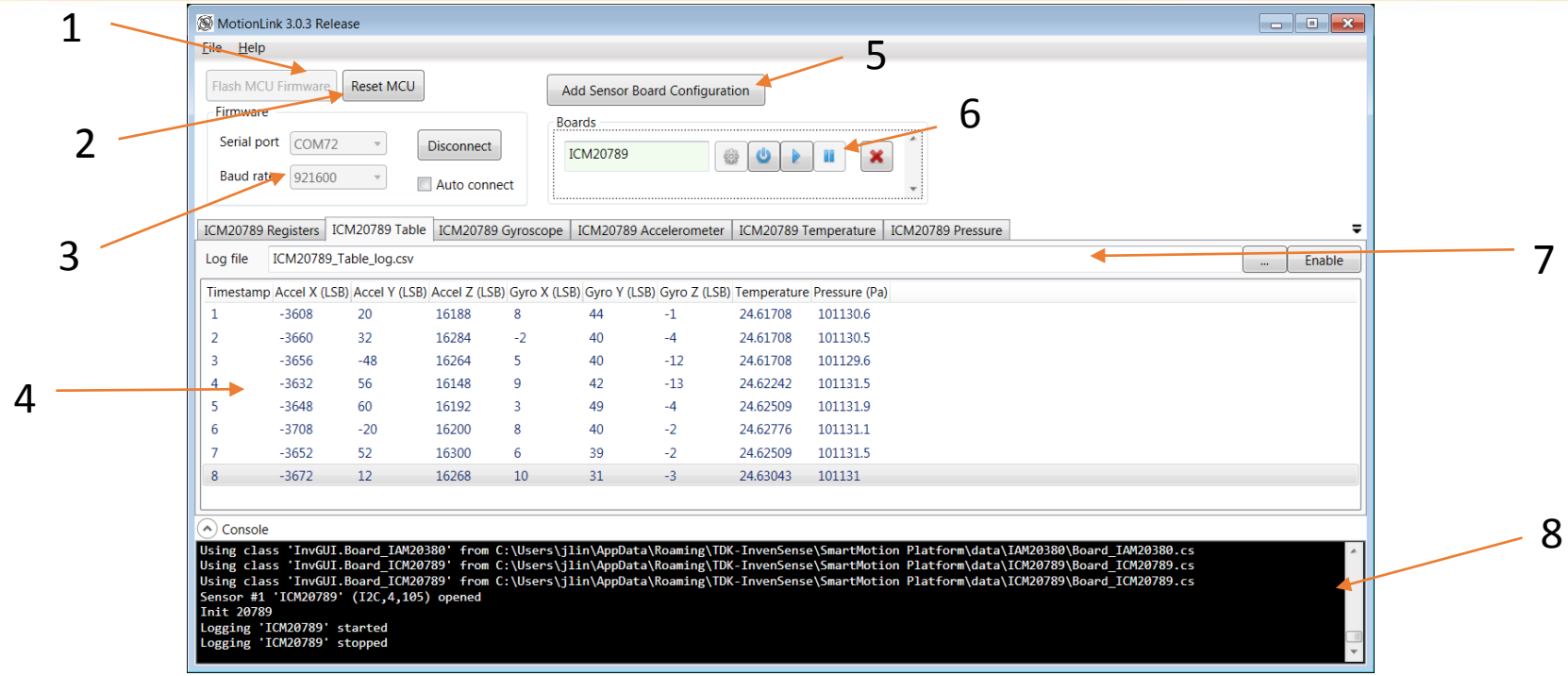


SmartMotion Hardware is pre-flashed with MotionLink!

SmartMotion Launcher page – select between using eMD or MotionLink

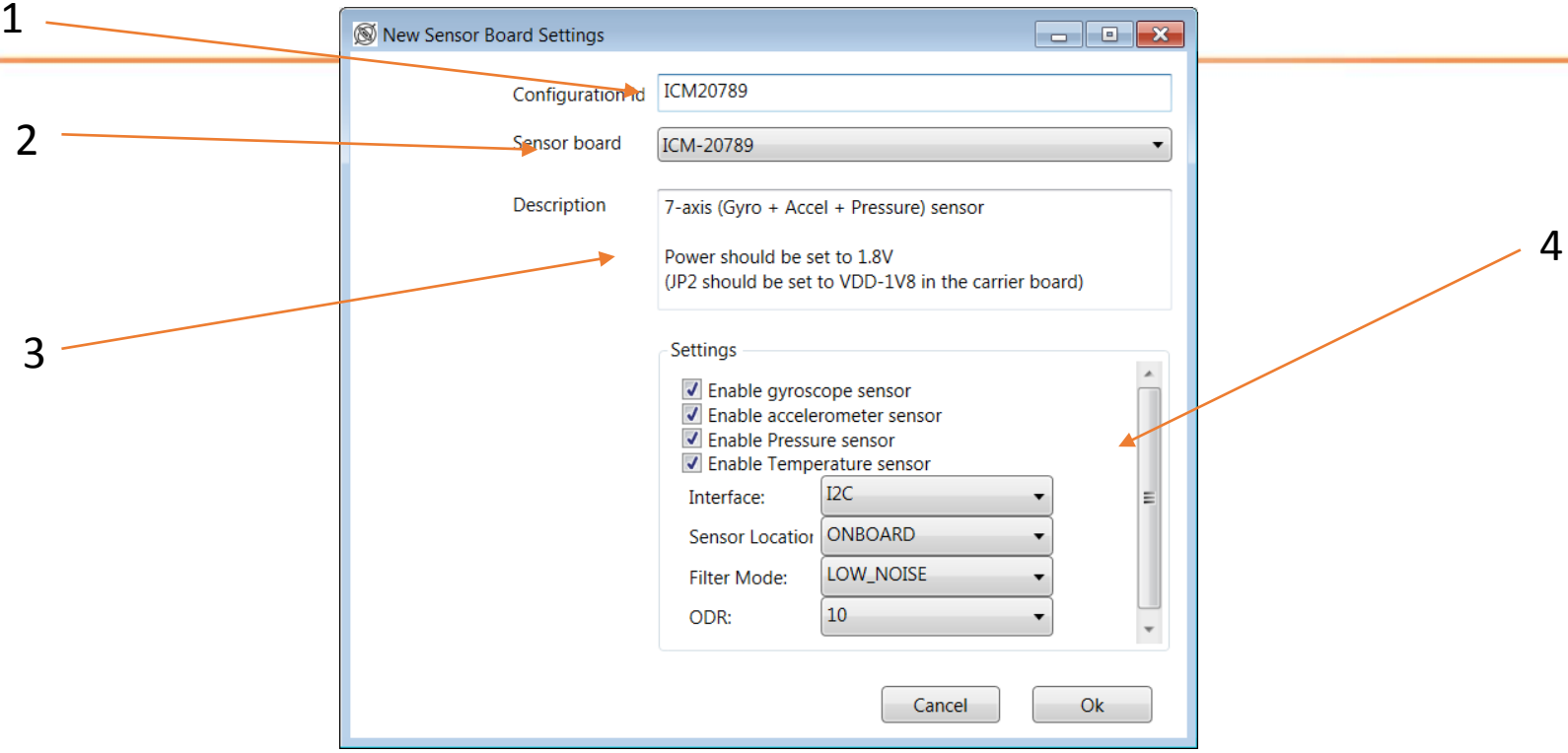
1. eMD Software – flash Atmel G55 MCU with a released version of eMD
    - SmartMotion Installer will have a version of the eMD release
    - Allow customers to browse for MCU images to flash
2. 'Start eMD' - Will open up the 'sensor-cli' command window used for eMD interface
3. MotionLink Software – will start up the MotionLink GUI

MotionLink Features



1. Flash Firmware – flash G55 MCU with MotionLink firmware or base eMD. Requires Atmel Studios!
2. Reset MCU – erases the firmware on the MCU
3. FTDI COM port connection – connect to the FTDI COM output. (not the EDGB COM port)
4. Data Output Console – displays requested data through the tab windows, registers, sensor data, and graphical data
5. Sensor Board Configuration – Adds target sensors to be evaluated
6. Sensor Board Control – Initialize and capture data control
7. Log File Output – can specify text log file for the sensor data if requested
8. Message Console Output – outputs error and status messages

MotionLink Features



Adding New Sensor Board Configurations

1. Configuration ID – Customer customizable ID for that particular sensor board configuration to be added
2. Sensor Board – drop down list on the full motion parts to be selected
3. Description – short description on the selected parts
4. Sensor Settings –
    - Customer can specify on which hardware sensor to stream
    - Specify I2C or SPI interface
    - Sensor Location if on board or attached external sensor EVB (on-board I2C address is always 0x69 while external I2C address is always 0x68)
    - Filter Mode to either Low_Noise (high power) or Low_Power (higher noise)
    - ODR selectable up to 1Khz

Embedded Motion Driver (eMD) : Getting Started

SDC - October 2017

Installing the PC Software

3rd Party Software Drivers for Hardware –

- ATMEL Studios – free Atmel IDE for all Microchip/Atmel MCUs
  - ¬ Required to flash and trace code
  - ¬ As of release MotionLink and eMD developed using Atmel Studio v. 7.0.1417
  - ¬ http://www.atmel.com/microsite/atmel-studio/

- FTDI Driver - http://www.ftdichip.com/Drivers/VCP.htm

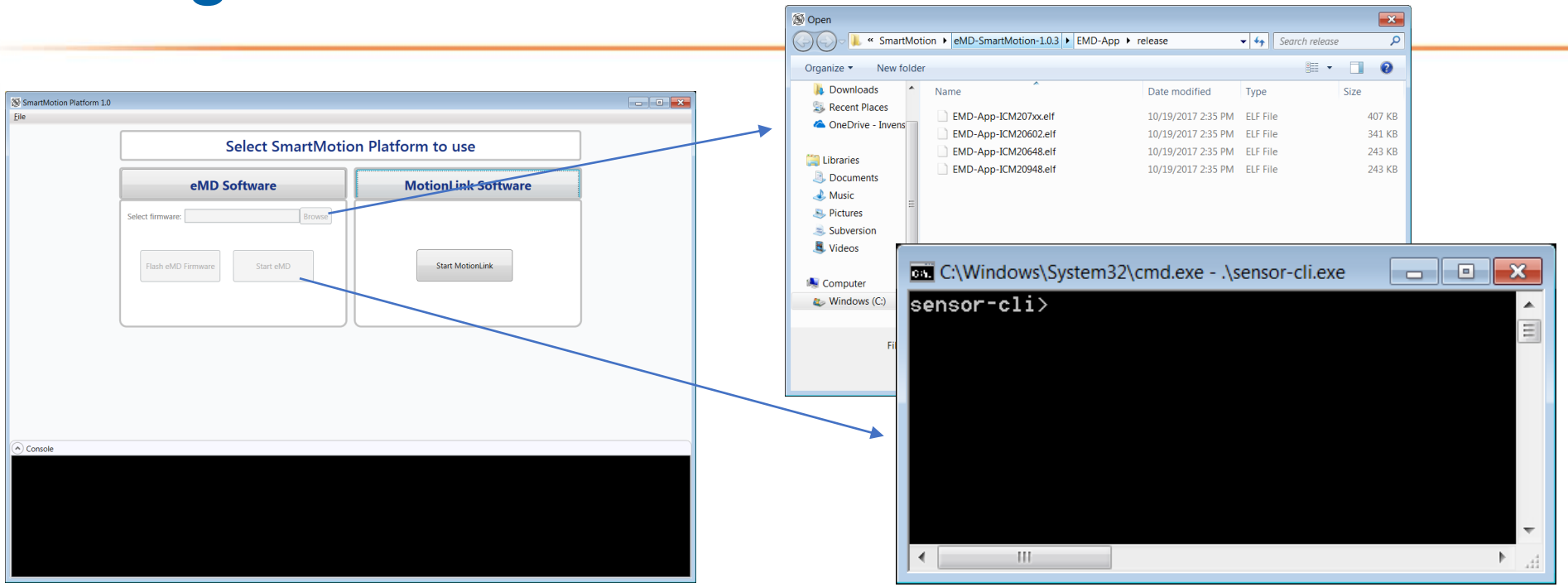
Install TDK-InvenSense eMD – 2 Options

- Option 1 – Download 'SmartMotion Installer'. SmartMotion Installer will have a base eMD that can be downloaded to the MCU
- Option 2 – Download latest 'eMD for SmartMotion' Atmel Studio project to be compiled and download to the MCU

https://www.invensense.com/developers/software-downloads/

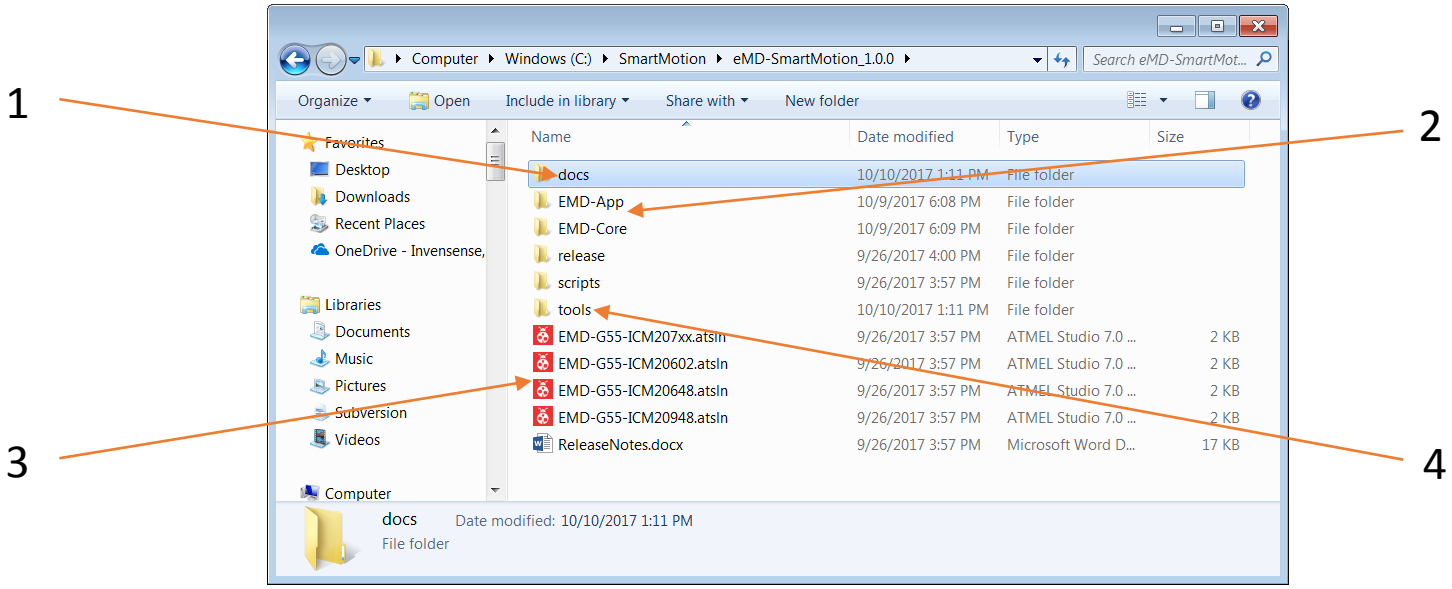
Connect SmartMotion platform and to PC

Using SmartMotion Installer for eMD



- SmartMotion Installer comes with feature to flash and use the eMD firmware
  - ¬ Requires Atmel Studio
  - ¬ Release eMD image but possibly an earlier version
  - ¬ MotionLink feature will not be able to function if using eMD
- In SmartMotion Launcher page click “eMD Software” to start the process
- Selecting “Browse” for will bring up a directory with pre-installed eMD images (.elf files)
- Selecting “Start eMD” will bring up a sensor-cli window

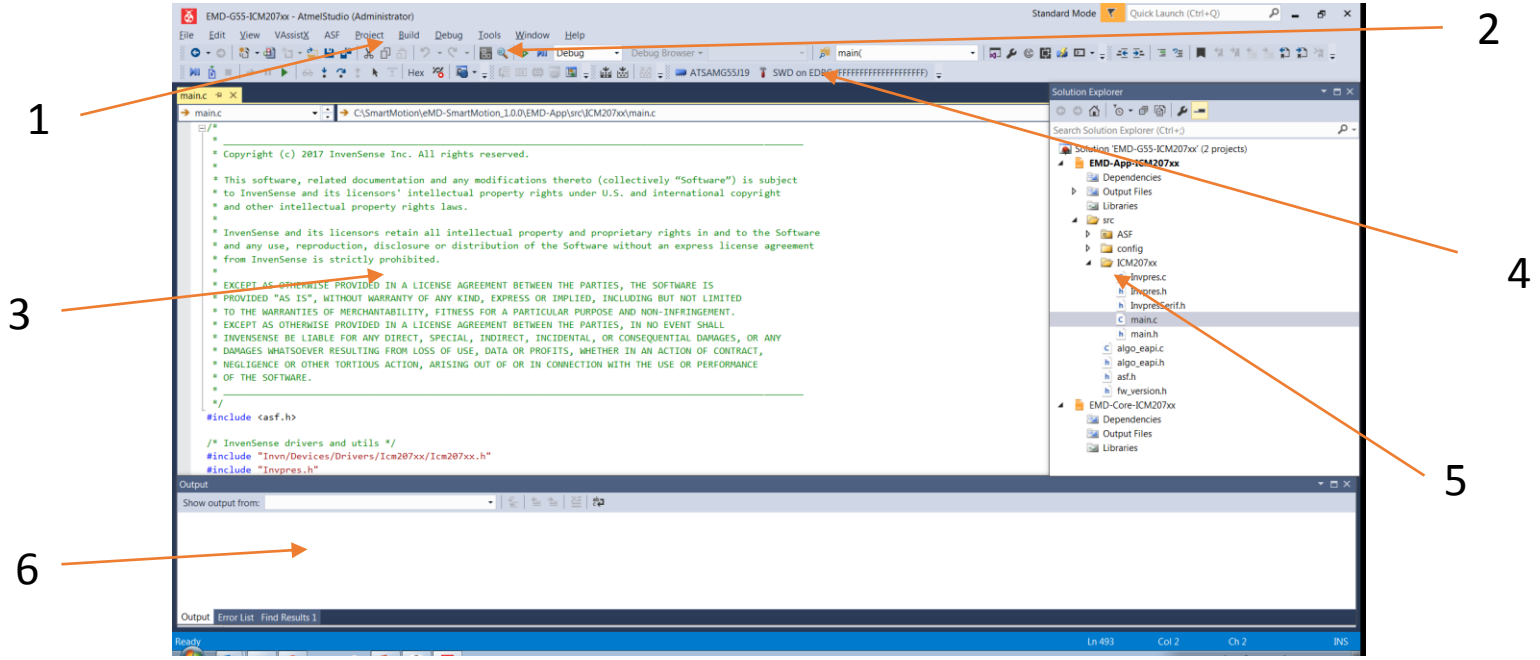
eMD - Atmel Studio Project



eMD Release Package

1. Docs directory : contains detailed SW User Guides and other documentations
2. EMD-App and EMD-Core : contains main driver code. ‘App’ has the main.c as well as board specific files. ‘Core’ has the libraries as well as the sensor driver files.
3. Atmel Studio Project Files : A specific main project for each SmartMotion platform to be opened in Atmel Studios
4. Tools directory : Contains ‘sensorcli.exe’ the command line tool to interface with the eMD

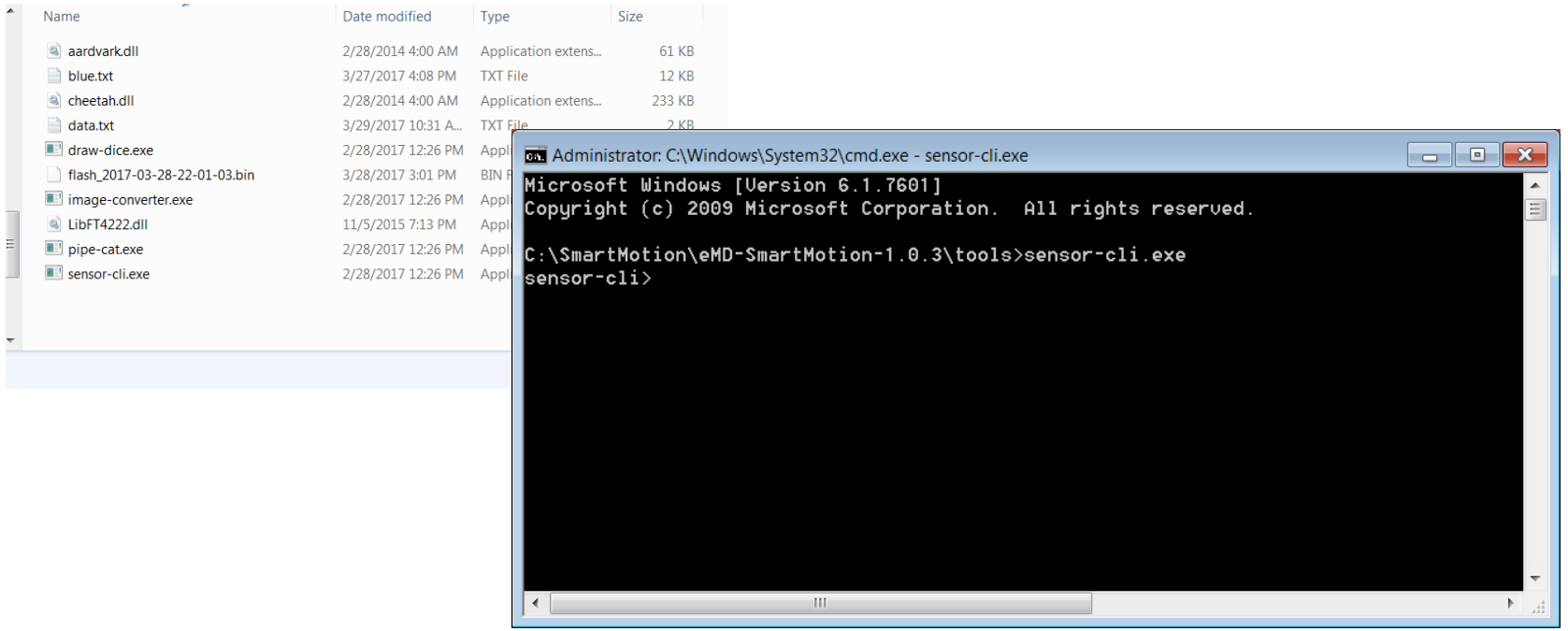
eMD - Atmel Studio Project



Quick Overview - Atmel Studio IDE

1. Control Tabs – Pull down tabs to build and compile project
2. Debug Controls – Used for code tracing
3. Main Code Console – display selected code
4. Target – targeted MCU and also debugger, make sure it is specify to ‘ATSAMG55J19’ and ‘SWD on EDGB’
5. Project Tree – directory of all project files
6. Debugging and Message console – misc messages from IDE

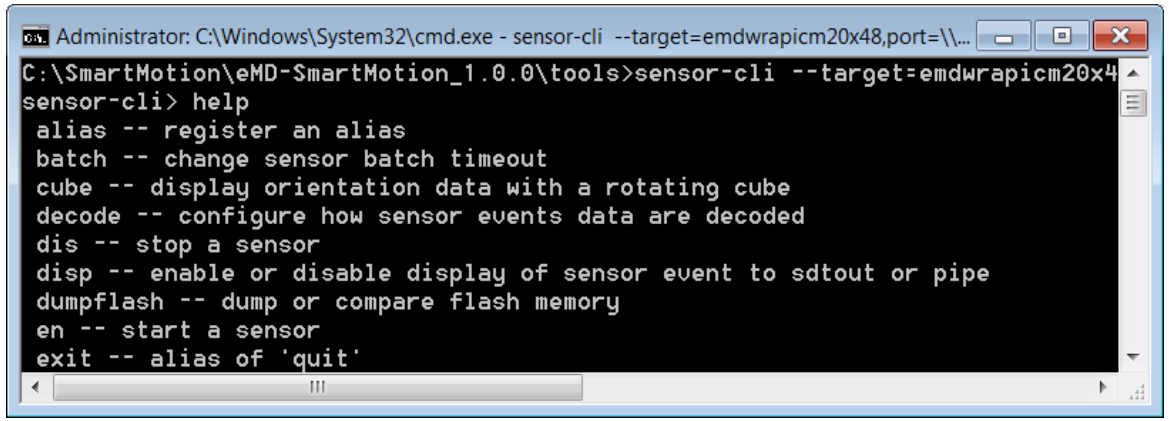
SmartMotion eMD – using sensor-cli.exe



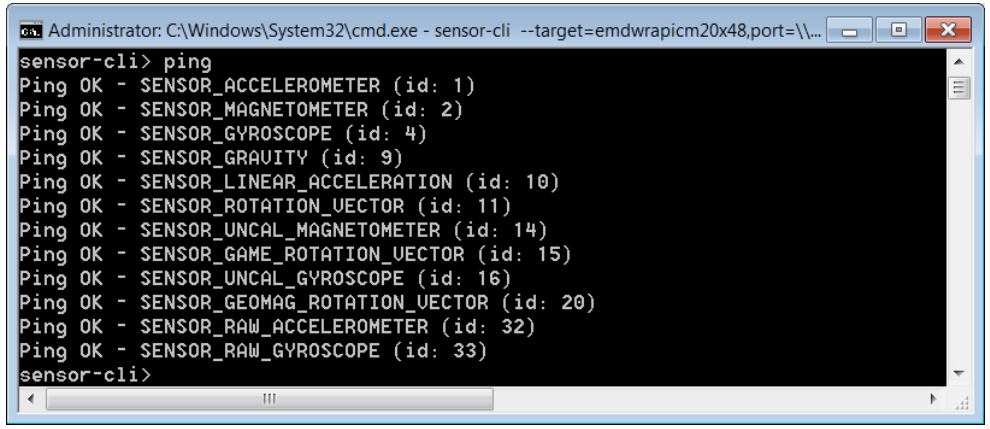
- 'Sensor-cli' is the command line tool which interfaces with the eMD and the SmartMotion board
  - ¬ Open 'tools' directory in release package, you should see the sensor-cli.exe along with other drivers
  - ¬ Open Command Prompt at the directory location and execute the sensor-cli.exe by running command
    - If only 1 SmartMotion hardware is connected to PC
      - 'sensor-cli.exe'
    - Multiple SmartMotion – 'sensor-cli --target=emdwrapicm20x48,port=\\.\COM66 --adapter=dummy'
      - Target argument will be specific to the SmartMotion platform, see SW User Guide for target
      - Port will be the FTDI COM port, can be found in PC Device Manager
  - ¬ If successful you will see a 'sensor-cli>' prompt on the command window

SmartMotion eMD – common sensor-cli.exe commands

- sensor-cli.exe has full range of commands to interface with the eMD specifies in SW User Guide
- Useful Commands
  - ¬ ‘help’ – displays set of commands and input arguments. You can also ‘help <command>’

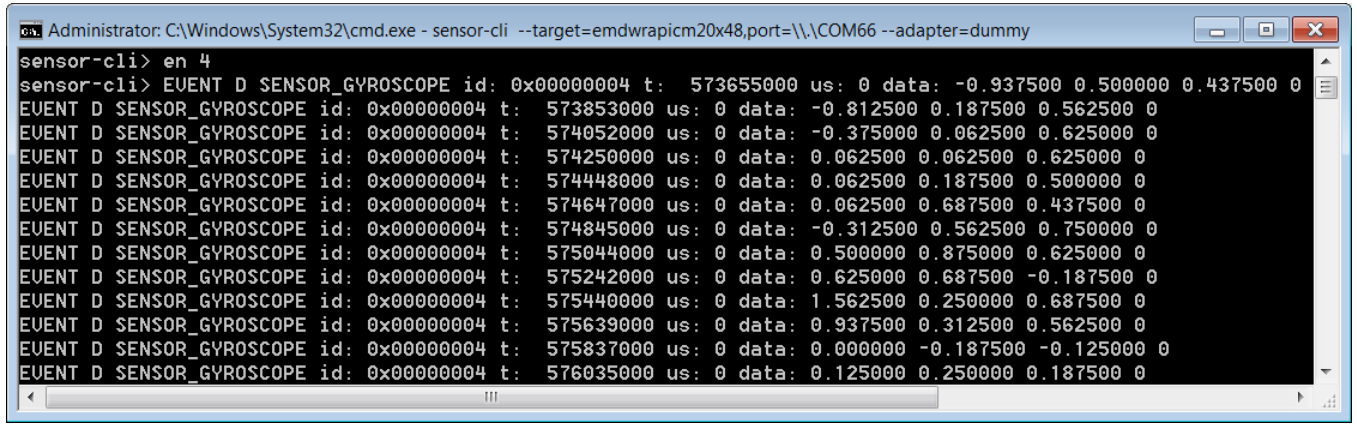


  - ¬ ‘ping’ – displays all sensors available and their IDs



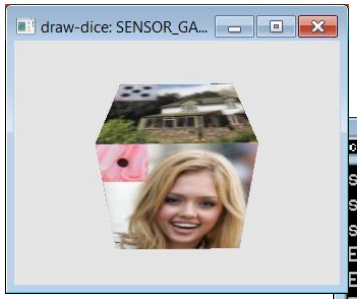
SmartMotion eMD – common sensor-cli.exe commands

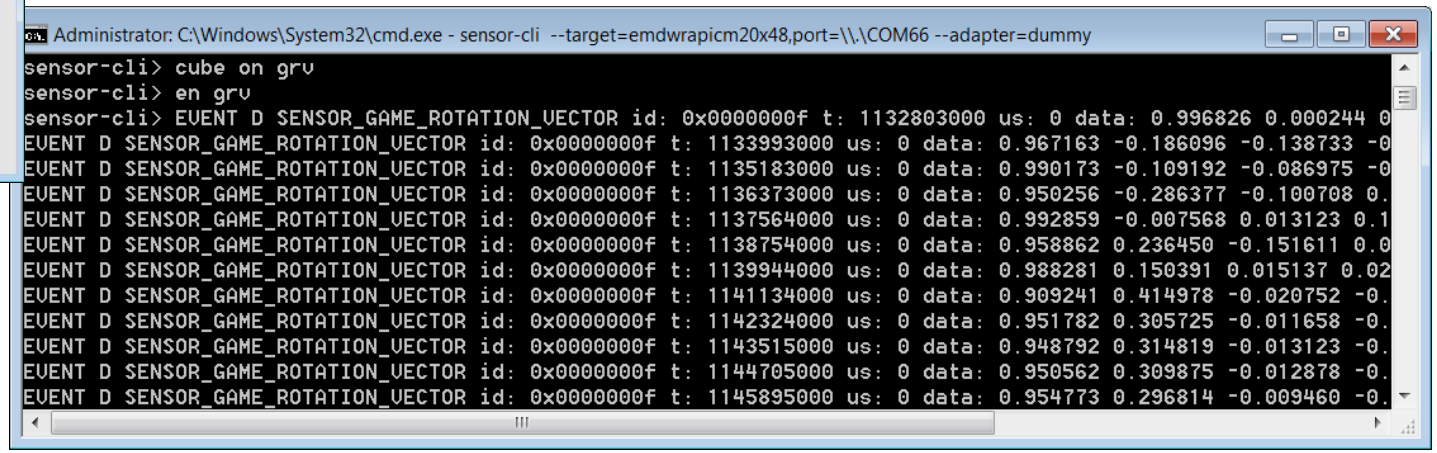
- Useful Commands continued…
  - ‘en <sensorid>’ – streams the sensor data to console. ‘dis all’ will stop streaming



SmartMotion eMD – common sensor-cli.exe commands

- Useful Commands continued…
  - ¬ Displaying the cube
    - ‘cube on <sensorid>’ – the cube window will appear but will not move until you enable the sensor. Best results are to use fusion sensors like Rotational Vectors (‘rv’ or ‘grv’)
    - ‘en <sensorid>’ – the sensor will start streaming to console, you will see the cube move based on the sensor data.





  - ¬ Other commands –
    - selftest, setting ODRs, bias configurations, logging, etc….

External Sensors

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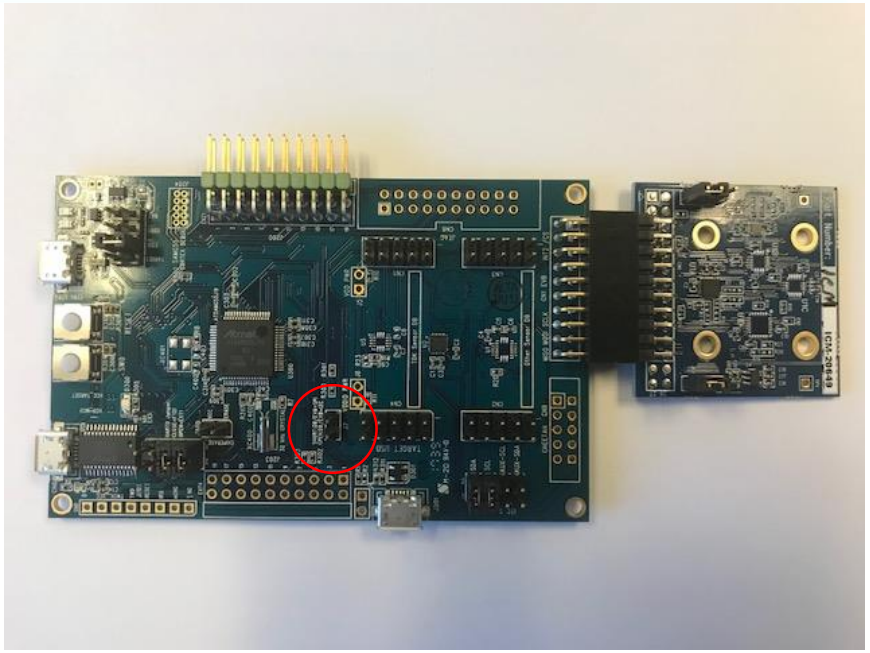
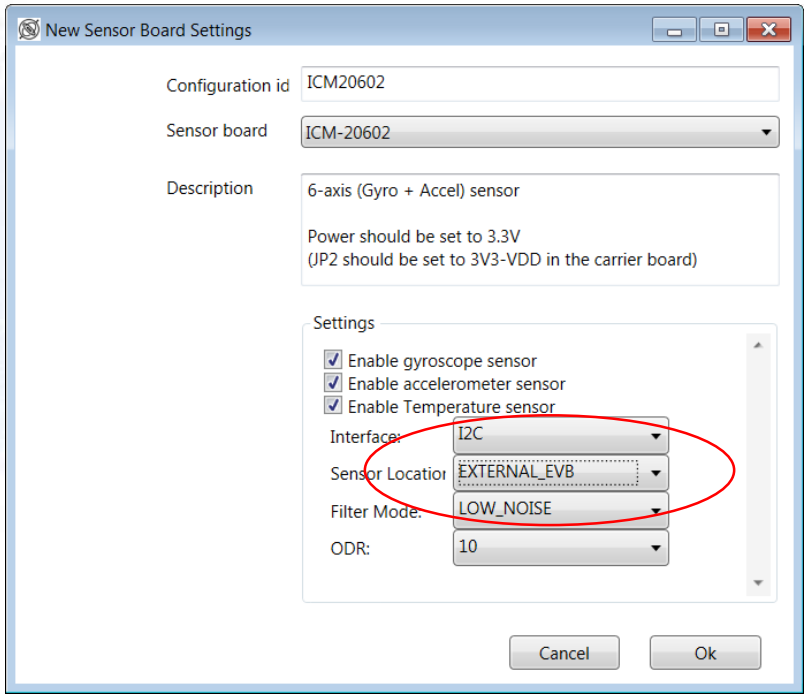
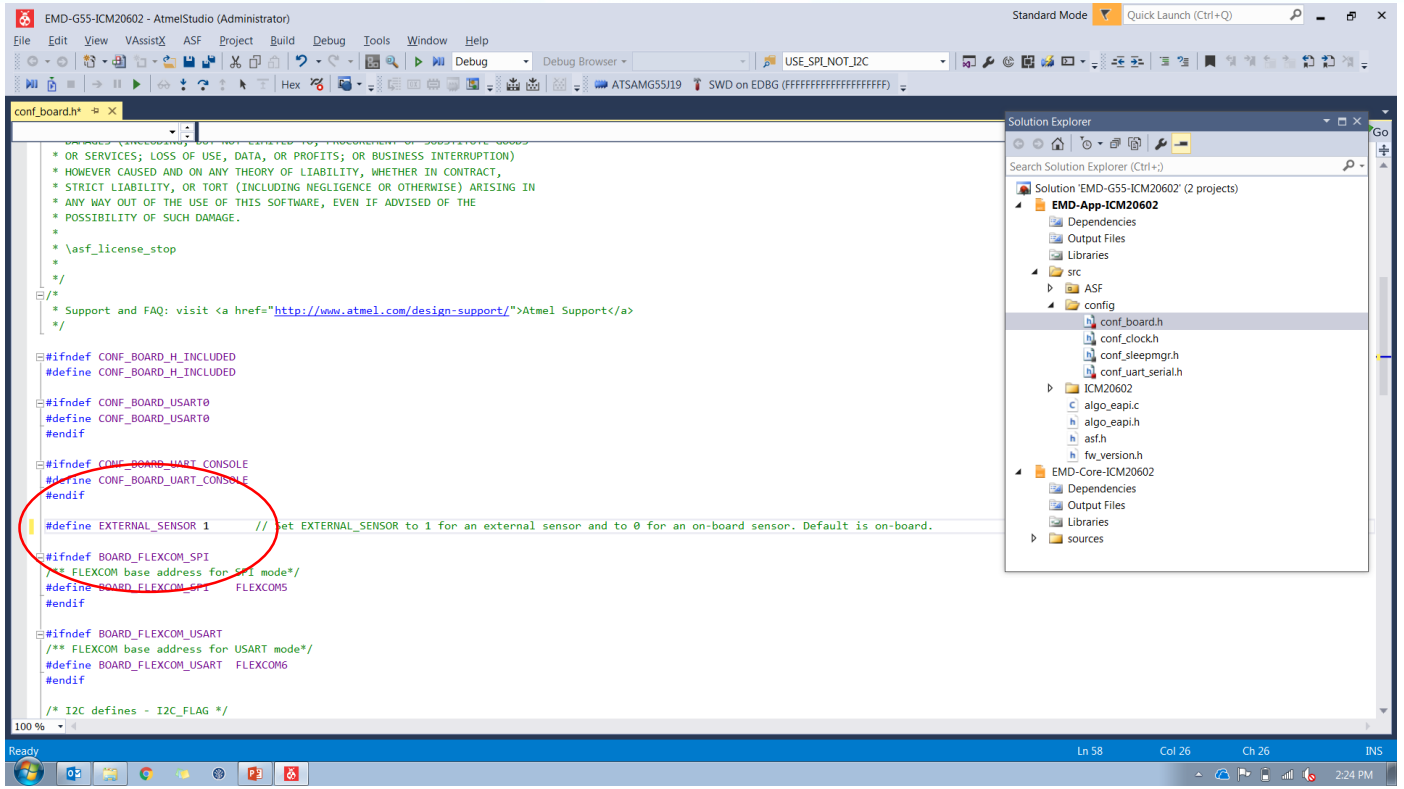
Connecting TDK-InvenSense Motion EVBs



- TDK-InvenSense motion EVBs are sold separately and can be connected to the SmartMotion Platform
- MotionLink and eMDs can interface with the EVB if supported
  - ¬ Motion parts which requires 1.8V VDDIO cannot be supported (ICM-20789 and ICM-20948)
  - ¬ External EVB requires eMDs to change to I2C address 0x68
  - ¬ Jumper J7 – interface to external EVB
    - I2C – Open
    - SPI – Closed
    - ICM-20602, ICM-20648, ICM20948 eMD are default SPI
    - ICM-20789 eMD are default I2C

MotionLink and eMD– External EVB Connection





MotionLink – Select EXTERNAL_EVB as the location when adding new sensors

eMD – conf_board.h , set EXTERNAL_SENSOR flag to ‘1’

eMD Porting Guidelines

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eMD Porting Guidelines

- MCU requirements
  - ¬ Atmel G55
    - Cortex M4 wth FPU
    - 120Mhz CPU Speed
    - 512Kb flash, 176Kb SRAM
    - I2C, SPI, UARTS
  - ¬ eMD v 1.0.3 Current Memory
    - 120Kb to 140Kb flash
    - 20Kb SRAM
    - SPI or I2C support

- Sensor Fusion
  - ¬ DK-20648 and DK-20948 - on board DMP
  - ¬ DK-20789 and DK-20602 – MCU sensor fusion library

- Tool Chains –
  - ¬ Atmel Studio - GCC compiler

Take Aways

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SmartMotion : Accelerate Product deployment

- SmartMotion provides everything to evaluate and develop applications with TDK-InvenSense motion sensors
  - Simple to set up, easy to use
  - Software toolchains are free
  - No external debugger required – saves $$$
- Affordable : $99 ASP
  - Widely available at TDK Distributors (DigiKey, Mouser, CDI, Avnet) at $99
- MotionLink enables easy evaluation of the sensor hardware
- eMD includes sensor fusion and motion algorithms

TDK-InvenSense SmartMotion Support

- **TDK-InvenSense SmartMotion Website -**
  - **https://www.invensense.com/smartmotion-platform/**

- **General Tech Support - techsupport_NorthAmerica@invensense.com**
- **General Sales Support – sales.us@invensense.com**

Thank you!