STING – INTERNSHIP REPORT

Post Silicon Validation

Automotive Microcontroller AURIX

May – October 2021

WESTPHAL SCHWAMBACH Jessé

University supervisor: HAMIDA Mohamed

Infineon internship supervisor: PLEZER Christoph

University: ECOLE CENTRALE DE NANTES - C2SystEm

Host organizations:

- INFINEON TECHNOLOGIES AG Siemensstraße 2, 9500 VILLACH - AUSTRIA
- ECOLE CENTRALE DE NANTES 1 Rue de la Noë, 44300 NANTES - FRANCE

Contents

Abstract

In order to validate the Embedded Systems and Power Grids studies at Ecole Centrale de Nantes, I did an internship inside the Automotive Microcontroller Post-Silicon Validation department of Infineon Technologies starting in May 2021 and lasting until October 2021.

The development of a microcontroller is a complex task that requires many people involved working on different modules and phases of the process. Simulators are getting closer to reality and are also primarily used by Infineon to check such a device. However, there are still features that can only be validated using the actual silicon component. In addition, the automotive industry uses such devices to perform the most critical functionalities inside a vehicle, such as airbags, bumpers, and brake systems, requiring a rigorous safety protocol to confirm that the system is robust assertive.

The mission of this internship is to compose the Validation team for the most critical event at the MC VAL team: the release of the new family of Infineon's microcontrollers AURIX 3rd generation. I worked on the Power Management System group, mainly coding the automation algorithm for the test sequences. Other tasks were performed as well, all of them related to the validation process.

Initially, the company will be presented and the department, division, and laboratory (chapter 1). After that, in chapter 2, there is an introduction about Infineon's Microcontroller, emphasizing the module PMS (Power Management System). The usual tasks, equipment used, and the theory behind it will be shown in chapter 3, followed by the administrative management of the validation preparation process in chapter 4. Chapter 5 report the work-related information, as training, first tasks, and meeting routine. Chapter 6 describes the work related to soldering, and Chapter 7 outlines a side project with Peltier modules.

List of Abbreviations

MC = MCU = Microcontroller Unit

AG = public limited company

R&D = Research and Development

ESD = Electrostatic Discharges

EPA = ESD Protected Area

IC = Integrated Circuit

PMS = Power Management System

EVR = Electronic Voltage Regulator

LVD = Low Voltage Detection

PORST = Power On Reset

DUT = Device Under Test

ADC = Analogic Digital Converter

PCB = Printed Circuit Boards

SAR = Successive approximation

OV = Over Voltage

UV = Under Voltage

SMD = Surface Mount Devices

DVS = Device Validation Specification

PTE = Product Test Engineer

IP = Intellectual Property

1 The company

Infineon Technologies AG was founded in 2000, originated from the Siemens semiconductor division. In the same year, the facility and the production area were purchased from CVEM in Hungary.

Nowadays, Infineon is a globally leading semiconductor company, counting approximately 52280 employees. The primary actuation sectors are automotive, power management and drives systems, sensor systems, connected, secure systems, wireless combos, and differentiated memories. Following the acquisition of the US company Cypress Semiconductor Corporation in April 2020, Infineon is now a global top 10 semiconductor company.

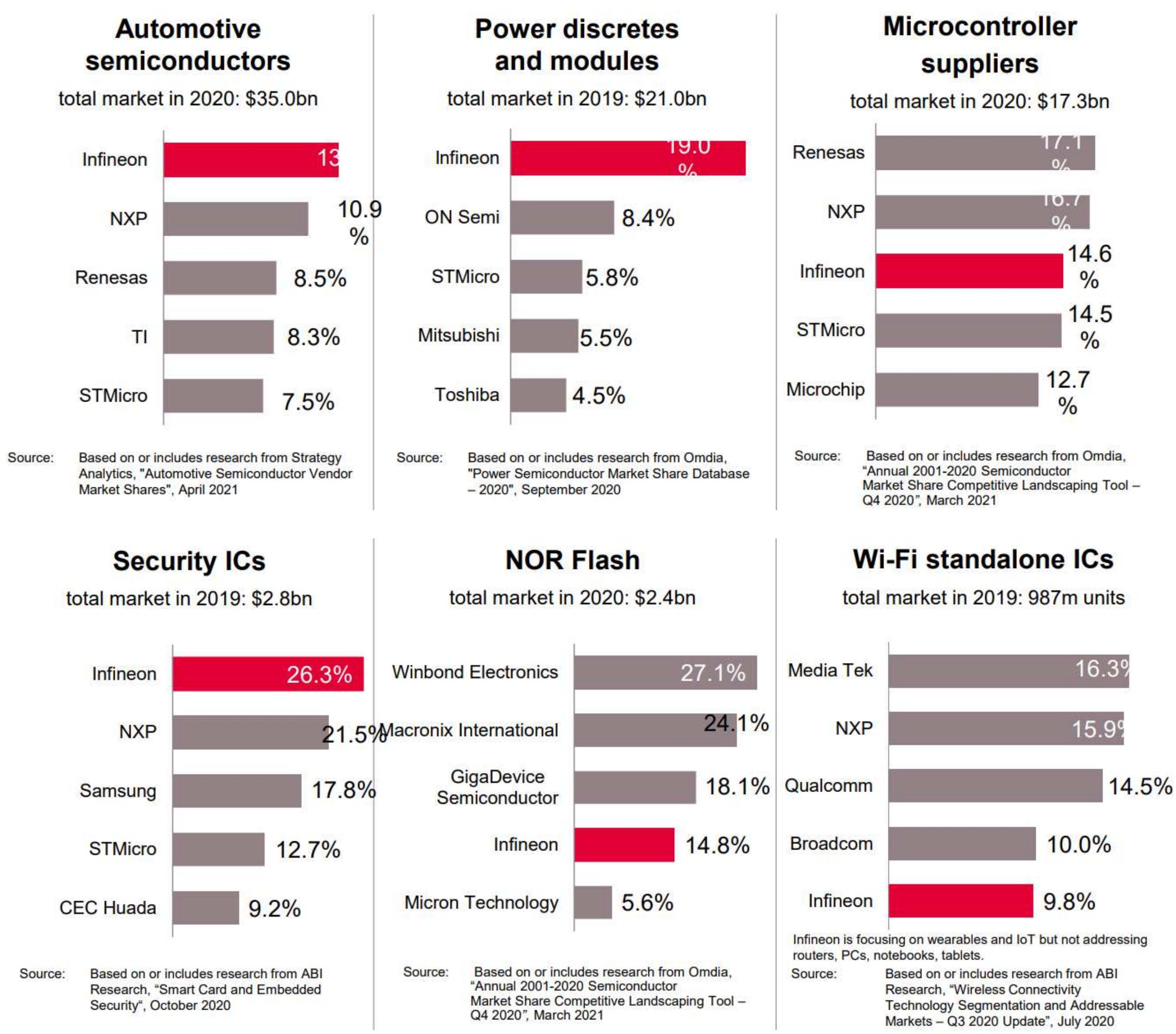


Figure 1 - Infineon's market part on different sectors

Infineon Technologies Austria AG is a group subsidiary of Infineon Technologies AG. Infineon addresses the central global challenges of energy efficiency, mobility, and security with its semiconductor and system solutions. With 4,517 employees from around 70 countries, including 1,960 in research and development, in the financial year 2020, the company achieved a turnover of € 3.1 billion. An R&D expense rate of €498 million makes Infineon Austria one of Austria's most substantial industrial research companies.

Figure 2 - Infineon Austria

Infineon organizes its operations in four segments: Automotive, Industrial Power Control, Power & Sensor Systems and Connected Secure Systems.

1.1 Automotive division

Semiconductors are essential for supporting the automotive megatrends: electro-mobility, automated driving, connectivity, and advanced security. Infineon products link the real and the digital world, driving the ever-advancing pace of automotive digitalization. The products have different complexities, from a simple sensor to an Automotive Microcontroller, the AURIX family.

1.2 ATV MC VAL Team and Lab

The AURIX microcontroller is the most complex product conceived by Infineon. Automotive applications have high standards when it comes to performance and reliability, the reason why the Validation team counts with more than 100 people working on testing every single functionality before the release of the microchips. The group I work with is called IFAT DCV ATV MC PD IP CPS VAL, with 20 engineers/students divided into three sectors: Power Management System, Converters, Application Pattern.

1.2.1 Calibration

According to the ISO26262, no measurement can be performed with uncalibrated devices. Infineon has calibration stickers, which indicate the internal serial number and the validity. The lab secretary is responsible for taking the devices to the calibration division inside the company one month before the device calibration validity.

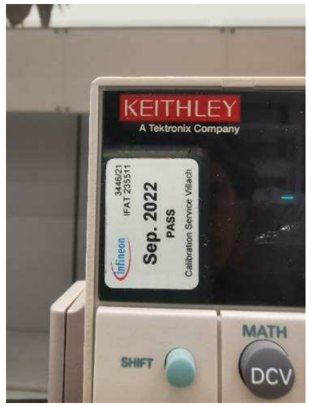


Figure 3 - Calibration Sticker on Multimeter

1.2.2 Electrostatic Discharge

Static Electricity means that it is a motionless electricity instead of flowing. Two surfaces that went through an electron separation process can interact to balance their amount of charge, using the air as a conduction medium, a phenomenon known as electrostatic discharge.

Working with microcontrollers requires extra care about Electrostatic discharge. Most of the ESDs go unnoticed by people and can destroy vital samples and ruin long-term tests. To avoid it, ESD equipment is available to all lab employees and should always be used inside the lab.

Some of the equipment are listed below:

1. **ESD Shoes / ESD Stripes:**

To enter the lab is necessary to have EPS shoes or ESD stripes and perform an electrostatic discharge test. The entrance is confirmed via an Infineon employee's badge that is required to unlock the door.

Figure 4 - ESD Shoes

Figure 5 - Lab Entry - ESD Shoes test

1. **EPA test bench / Chairs / Cupboards / boxes for Microcontrollers:**

The EPA chairs need to be checked periodically to assure the ESD protection capability.

The DUT is stored after its use, and it is mandatory to put them inside an EPA box to keep the chips safe from electrostatic discharges.

Figure 6 - EPA box for Microcontroller

2 Microcontroller

A microcontroller unit (MCU) contains a CPU, memory, and input/output peripherals on a single integrated circuit (IC) chip and works as a small standalone computer. This allows for a reduction in power consumption, more compact designs, and cost savings. Additionally, microcontrollers can provide functional safety and security for embedded systems.

Increasingly, it is becoming critical that microcontrollers are equipped with advanced security features to avoid security compromises and prevent malware attacks.

2.1 Infineon's Microcontrollers

The Infineon microcontroller portfolio offers a comprehensive product range that includes state-of-the-art 32-bit microcontrollers that offer strong performance and future proven security solutions, along with traditional 8- and 16-bit microcontrollers. The 32-bit MCU product portfolio includes:

- XMC™
- TRAVEO™ II
- PSoC™
- Auto PSoC™
- FM™
- MOTIX™ Embedded Power based on Arm® Cortex®-M technology
- AURIX™, which uses TriCore™ technology

Infineon's broad portfolio of microcontrollers offers scalable and high-performance solutions for various applications for automotive, industrial, and consumer markets. The applications can are divided into the following areas:

- Smart Sensors / Auto General Purpose
- Driver Information & HMI
- Body & Connectivity
- Chassis & Safety
- Power Train & xEV
- ADAS

The microcontrollers are associated with these applications according to Annex 1.

2.2 TC3XX

The AURIX microcontroller TC3xx family, with its up to hexacore high-performance architecture and advanced features for connectivity, security, and functional safety, is ideally suited for a wide field of automotive and industrial applications. In addition to engine management and transmission control, targeted powertrain applications include new electrical and hybrid drives systems.

The second generation of Infineon's MC is being commercialized and is available in the validation lab to perform the measurements, tests and help prepare the AURIX 3G Validation.

2.3 TC4XX

The third generation of AURIX Microcontrollers is being developed and will be released in the future. With several new features and functionalities, these devices are one of the most complex systems Infineon develops, a challenge for all Infineon's ATV departments, including the validation team.

Figure 7 - Infineon A3G TC4XX

2.4 Power Management System

The Power Management System provides supply voltage selection, internal supply voltage generation, supply voltage monitoring, power domain and isolation control, and power management functions for the microcontroller. It supports other microcontroller infrastructure functions through reset triggers, standby mode transitions, and real-time clock services.

Several functionalities of the PMS module are related to the external supplies. An extract of the TC36 Microcontroller datasheet on Annex 2 shows the ramp-up and ramp-down for the supply mode A. Understanding the supply phases is the first step to understanding the Power Management System of the AURIX microcontroller.

The supply mode A counts with the internal generation of VDDP3 (3.3V) and VDD (1.25V). From T0 to T2, there is the EVRx start-up phase, which begins by the supply of VEXT at (0), passing through the latching of the Hardware configuration [6] and crossing the LVD reset threshold at (1), point where the internally generated voltages start-up is triggered and started, after some delay (point 2).

When the internal voltages and VEXT are above their threshold values at (3), the PORST signal gets HIGH, meaning that the MC can start the firmware execution. When this step is done (4), the user code is executed, the microcontroller is fully operational.

The controllers are robust to supply variation, as we can see on the figure during the ramp down. VEXT has its value decreased, but the internal voltages keep for some time the same value. When the regulators are not able to follow the reference voltage anymore, the voltage starts to drop. If one of the rails goes lower than its under-voltage reset threshold, the PORST signal gets LOW, and the functionalities of the chip cannot be granted anymore.

There are more supply rails involved in this process, these three being the principal ones. On the validation tests, all supply modes need to be checked, as well as oscillations on the rails, controller's gates transitions, the time between phases, different register settings, lower and higher valuer of the threshold voltage detection alarms.

3 Post Silicon Validation

3.1 Test bench

All the measurements are performed inside the Validation Lab, where each one of the department members has his test bench. The devices are available inside the lab cupboards, and the setup will vary depending on the tests assigned to the validation team member.

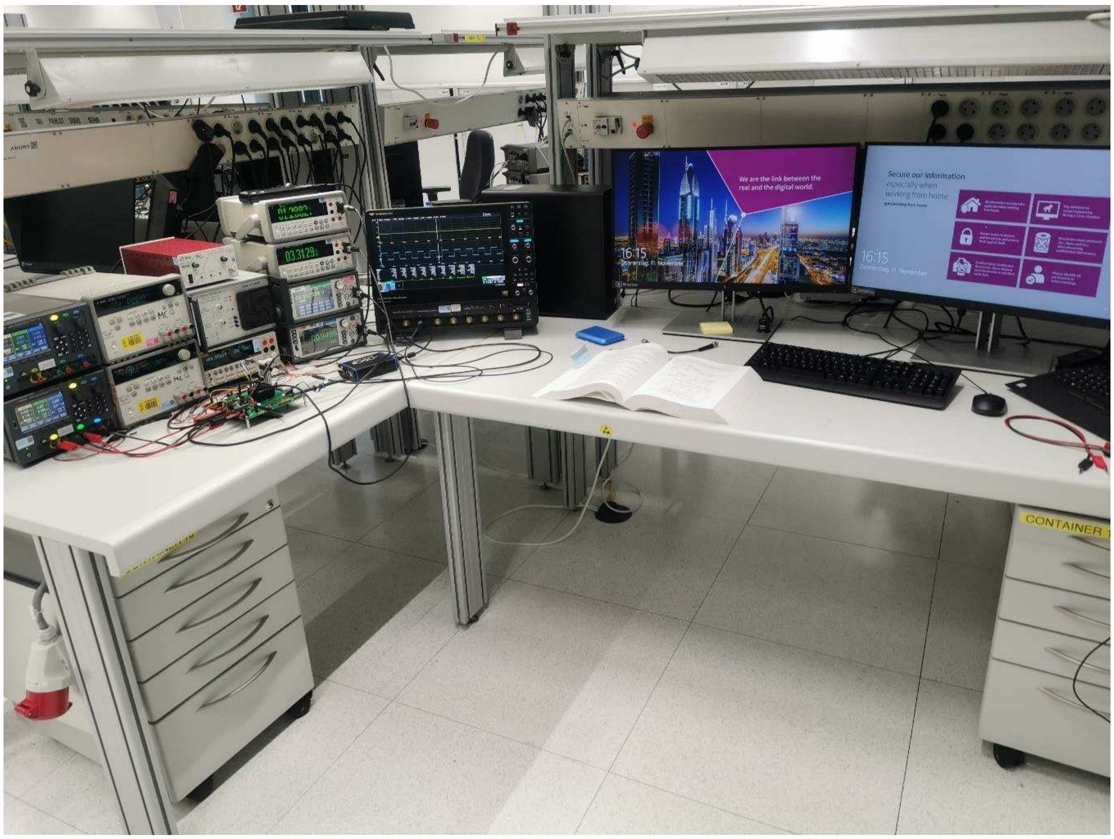


Figure 8 - Test Bench

The Figure 8 shows my personal instrument setup, used for tests and validation.

The devices have to be scanned and assigned to their current location. An integrated system is available for all the users to search for equipment and check the device status.

3.2 Equipement

The test bench equipment is what makes possible the whole validation process. The first challenge of this internship was to get used to the devices, know the functionalities, ways to connect, manual configuration, and remote commands. Figure 9 shows in detail the validation equipment.

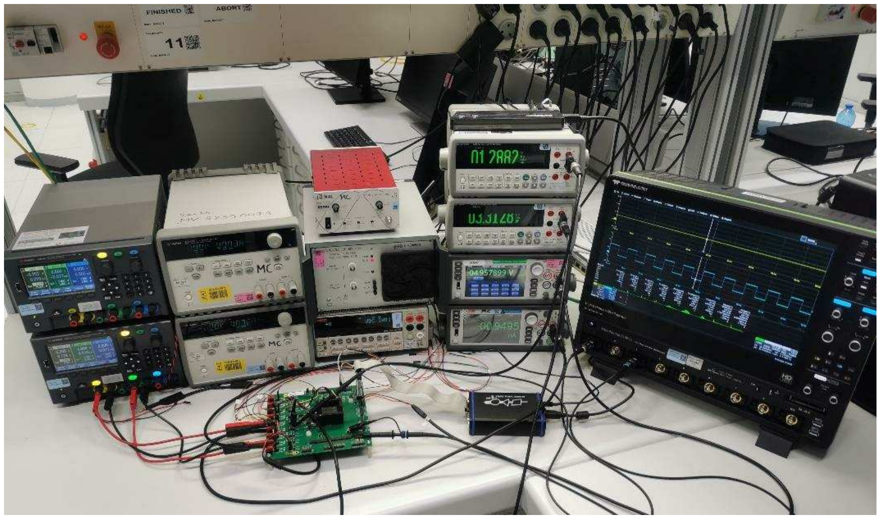


Figure 9 - Devices used for measurement

In this section, the devices' main functionalities are going to be presented.

3.2.1 Function Generator

Function generators can send specific signals to the sample. To see some behaviors of the microcontroller, parametrized ramps, pulses on a particular frequency, or even arbitrary functions need to be simulated and supplied.

For some measurements, the input rails drain more current than these devices can supply. In that case, a power amplifier needs to be connected in series between the function generator and the board to supply the current needed. The voltage is generally not a constraint for our measurements since the higher voltage supplied is around 7V.

Figure 10 - Function generator Agilent

Figure 11 - Power Amplifier N4L

In specific test cases, the power supply and a ramp supplied by the function generator needed to be synchronized. Since the remote control inserts a considerable delay, it could not be done by code. A trigger function inside the waveform generator was used to solve this problem, connecting the power supply output also to the trigger pin of this instrument. The waveform is not periodic. It only depends on the source of the trigger.

3.2.2 Power Supply

Power supplies are mainly used for static measurements (constant voltage supply) or when the transition between voltages is irrelevant. Most parts of the microcontroller supply rails keep constant during the test, and due to their simple concept, these devices are also easy to handle and program.

Figure 12 - Power Supply Keysight

The 4-wires measurement is a functionality available in some of them and is crucial to avoid losses in the conductors when the current gets higher. The idea is to have feedback of the voltage being supplied after the voltage drop on the supply cables.

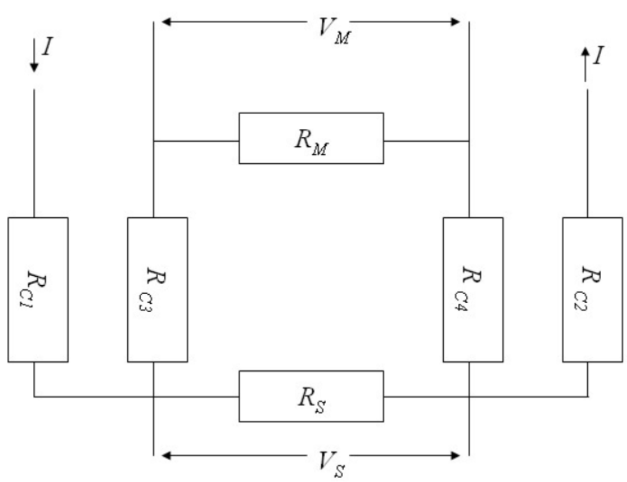


Figure 13 - Four wires measurement

Usually, the cables used to supply the MC's external rails have less resistance as possible – high diameter and short, on Figure 13 Rc1 and Rc2. Despite that, when the current gets high, the voltage drop on these small resistances impacts the voltage received by the DUT, being lower than the indication on the device. To solve this problem, the voltage is measured directly on the DUT by a voltmeter inside the power supply, which has a high-value resistance (Rm) and drains a negligible amount of current through the measurement cables (Rc3 and Rc4), that do not need to have that low of a resistance level.

3.2.3 Multimeter

Multimeters are used for static and precise voltage and current measurements. An example of its use is to check if the ADC conversions are correct, comparing it with the multimeter value.

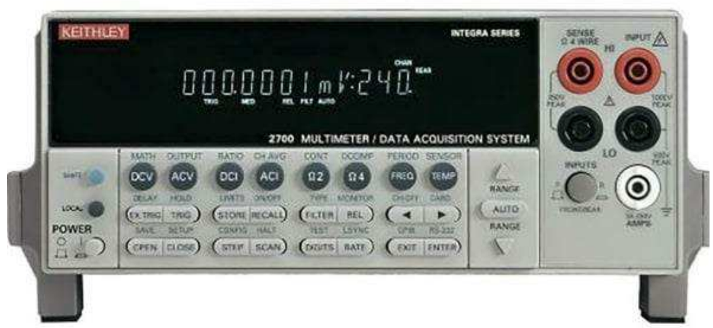


Figure 14 - Multimeter Keithley

Since there are several rails on the microcontroller and some of the tests are made for everyone, it would be impossible to automate a measurement without using more of these devices. The answer found is to use the multiplexer module, an extension of the standard multimeter that allows 40 parallel channels that can be set one at a time to get the desired rail measurement.

3.2.4 Current probes

Since there are several rails on the microcontroller and some of the tests are made for everyone, it would be impossible to automate a measurement without using more of these devices. The answer found is to use the multiplexer module, an extension of the standard multimeter that allows 40 parallel channels that can be set one at a time to get the desired rail measurement.

3.2.5 Current probes

The amperemeter measures the current of a circuit. It must be put in series with the circuit, meaning that the circuit is open to insert it, which is not ideal for a fast-flexible measurement. On the other side, current probes can estimate this physical quantity by the electromagnetic field generated when a current pass through a conductor.

3.2.6 Oscilloscope

Oscilloscopes are the most expensive measurement equipment inside the lab and consist of a test device that shows graphically dynamic signals with various measurement features implemented. The ones used in the lab are embedded PCs with great processing power and robustness.

Figure 15 - Rhode and Schwarz oscilloscope

3.2.7 Thermostream

To get the microcontroller to its limit temperatures, a device called Thermostream is used, which needs to be supplied with pressurized air and can supply temperatures higher than 170°C and lower than -50°C.

Figure 16 - Thermostream

Several tests are performed with different temperature conditions since this is an important parameter for the MC, interfering with the results that need to be inside the specifications range. The operation of this device can be automated, and usually, the value from the DTS (Die-Temperature sensor) is given as feedback to control the temperatures.

3.2.8 Device Connections

Almost all the devices used for measurements can be connected to a PC and controlled by it. This feature is essential for the automation of the test sequences and can be made by different protocols. Nowadays is used, GPIB, USB, and LAN connection protocols.

3.2.9 Base Board

Base-boards are PCBs made exclusively for testing the microcontrollers. They are built with easily accessible plugs for supply, measure, and connection with specific instruments, including a PC.

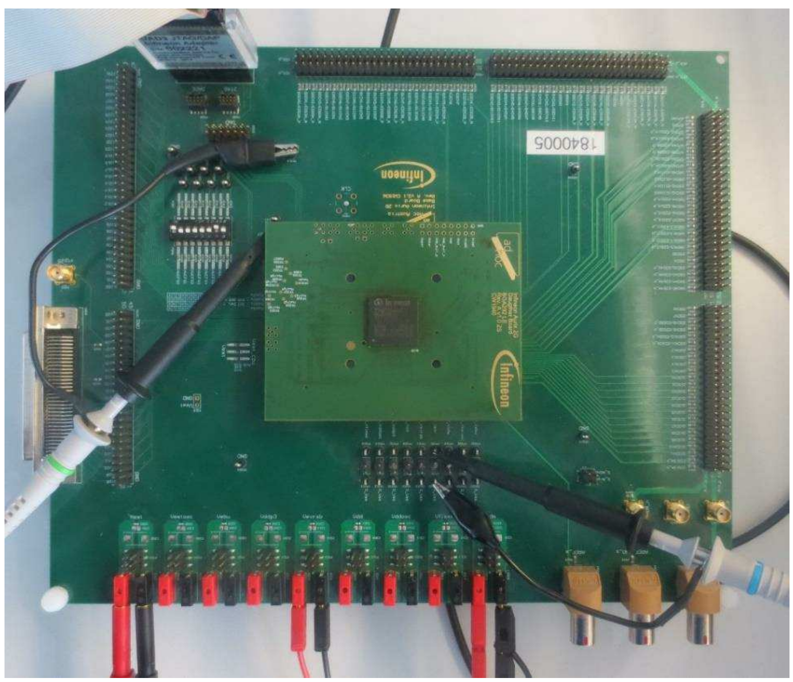


Figure 17 - Base Board Validation Lab

The hardware configuration selects the operation mode of the microcontroller. To change it and perform tests with all the modes with the same base-board, the PCB counts with switches that need to be set before supplying the chip. These switches control the Hardware configuration. The schematics are shown in Figure 18.

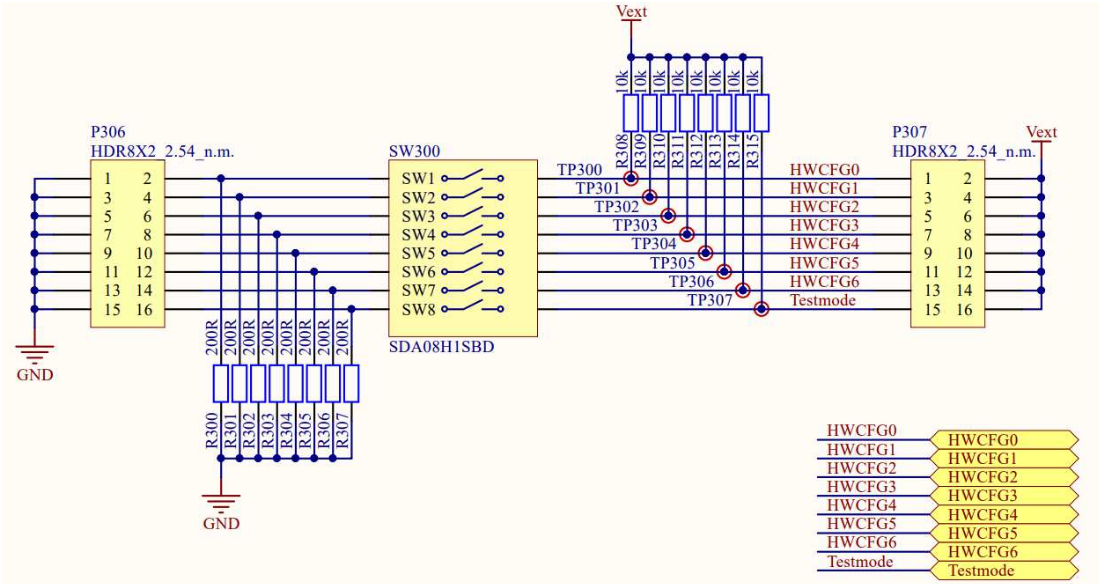


Figure 18 - Hardware Configuration Schematics

The hardware configuration should be set before supplying the MC and can only be changed after a reset. The designers decided to make this feature with a pull-up resistor: All the pins are connected to the supply with a high resistance resistor, having by default high logic level. Closing the switch connects the hardware configuration pin to the ground, and the voltage drop keeps over the 10k ohms resistor, level logic 0.

3.2.10 Daughter Board

Infineon's Automotive Microcontrollers can be used for several applications inside a vehicle, and because of that, the peripheral electronic components used for these applications also vary. Daughter-boards were created to avoid changing the base-board for every circuit simulation, d. The chips can be solder over this smaller board or placed in a socket and then embedded into the base-board.

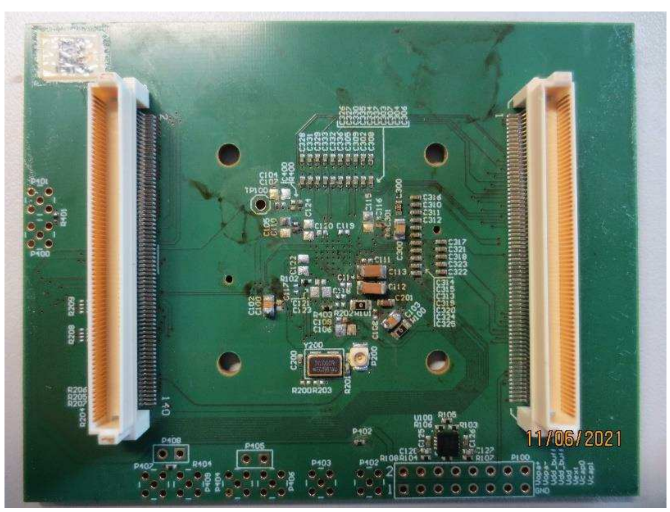


Figure 19 - Daughter board - Bottom side

Some tests require different capacitance, resistance, inductance values, or even different components. Therefore, the bottom side of these boards is accessible to have its elements unsoldered and soldered as many times as needed.

3.3 Devices Remote Control

For each device, there is a different syntax on how to send commands and receive data. The user manual contains all the remote commands specifications often used during the automation code construction.

3.4 Test Sequences / Automation

the first step to validate the functionalities and datasheet parameters of the microcontroller is to define a sequence of steps, including all the configurations, supplies, registers to be read/written, and values to be acquired. This is defined as a test sequence.

In the past, several tests were manually performed. The first generation of Infineon's automotive MC had much fewer features, supply rails, and registers. The complexity of the DUTs is increasing over time, which makes the old manual tests impracticable to be implemented. Therefore, using remote commands, it is possible to translate the test sequence into a programming code, in this case, to C#.

The programing environment chosen by the company is the Visual Studio, where Infineon developed a framework called TDEX to standardize the automation process. The user has access to some instrument classes on this application, whose methods are the instrument's functions (e.g., *readVoltage(multimeter))*. The manufacturer's manual has to be consulted whenever the classes for an instrument are not available, or the functions are too specific. Each one has a different syntax.

The algorithms always follow the same logic:

- **Initialization**

  The connection to the devices is established, and the first configuration of those instruments can be set.

- **Execution**

  The most used execution mode is with *test vectors*, which change every time the execution is performed. It is handy because the same execution is performed for different configurations, such as sample(different microcontroller), temperature, supply mode, rails, thresholds, and others.

  Before running the program, the user generates a table with the parameters needed for each iteration. When all the test vectors are executed, post-execution is called.

- **Post Execution**

  At this point, the instruments can be disconnected, outputs off, and a post-processing function can be called using the measured values.

3.4.1 Registers Reading/Writing

To read and write registers on the AURIX Microcontrollers, the Universal Access Device is used, connected to the base-board by JTAG cable. When the PORST signal is High, meaning the microcontroller is fully operational, it is possible to open a workspace in the UDE application and connect to the device. The registers can be added to a display page and be monitored/modified. Whenever the register is changed, it becomes red, as we see on Figure 20.

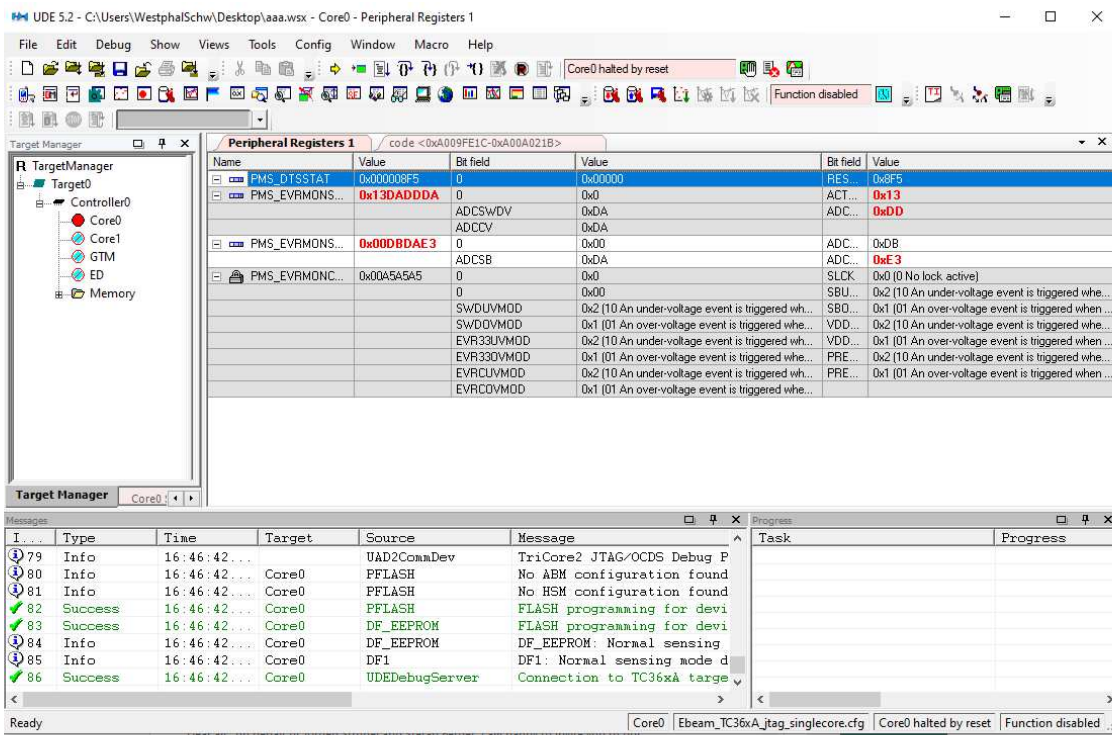


Figure 20 - MC registers on UDE application

The UDE application is often used for chip debugging. Since the security and monitoring features of the AURIX microcontrollers are innumerous, a non-expected behavior can be easily be checked on a bit on the registers.

The registers can also be accessed by code through UDE by giving the right hexadecimal addresses and/or input values as parameters.

This application can also update patterns that will require some processing power to be executed, simulating an actual customer application.

3.4.2 Test sequence Examples

The daily work is based on the preparation of test sequences. On the AURIX TC4XX validation process, confidentiality is paramount, and the majority of the information can not be presented in this report. Two test examples are listed below and correspond to actual validation tasks.

3.4.2.1 Time to PORST release

The purpose of this test is to run an automatic test sequence to validate the time to the PORST release after VEXT falling below Vthreshold (2.97V).

Hardware Configuration [01111101] :

- EVR33 internal
- EVRC internal
- HWCF6 in tristate

The supply mode, in this case, is the A, the same as the one explained in Annex 4.

Active pull-up => Switch put to OFF means HIGH tension level.

The circuit in Figure 22 - EVRC Output schematics is the external part of the EVR controller, which generates internal supplies according to the hardware configuration. The outputs coming from the chip are the P and N gates, switching the MOSFETs to allow VEXT or GND to be connected to VDD, passing by a filter circuit. VDD is used internally to supply the cores and converted by an ADC to serve as feedback for the regulator.

As we can see in Figure 21, the P and N-Gate MOSFETs work synchronized, and both cannot allow the passage of current at the same time. Otherwise, there would be a short between VEXT and ground because only 0-ohm resistors are between these rails. For a P-gate MOSFET to allow the current passage, the gate should have a high voltage level, and the opposite is applied for the N-gate. High impedance intervals (highlighted in red) are necessary to ensure the components will not short the circuit.

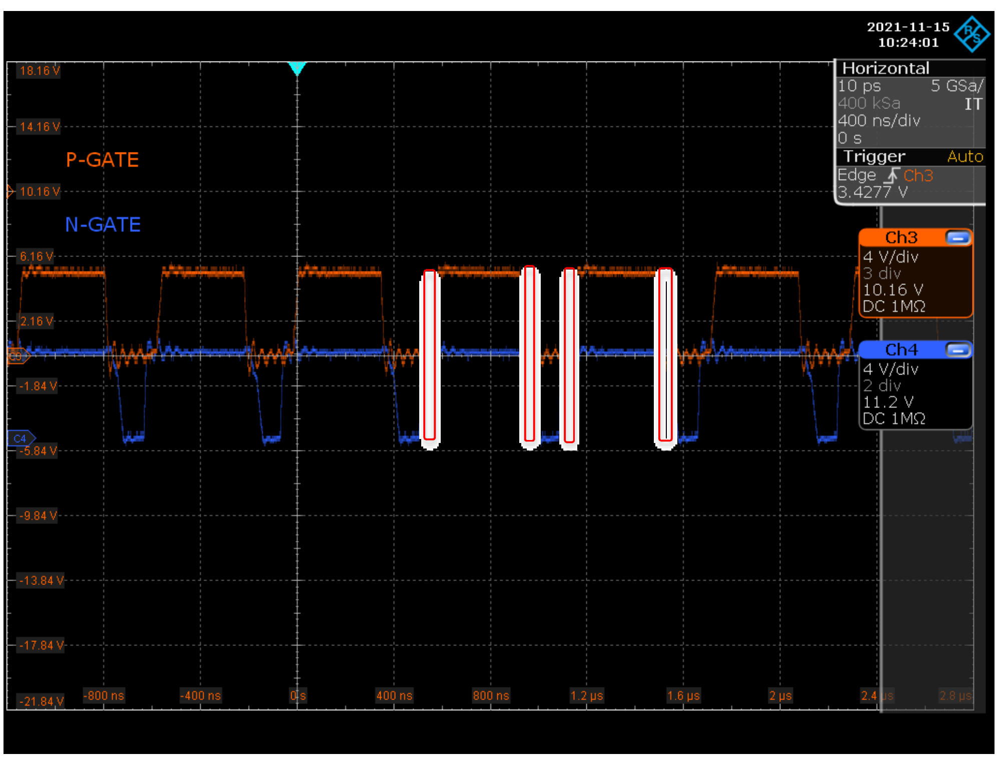


Figure 21 - EVRC P and N-Gate MOSFETs

For some of the tests in the lab, it is crucial to open the controller loop to avoid interferences when these rails are externally supplied. Thus, when a new sample daughter-board is tested and the internal supply mode is chosen, the validation engineer needs to check if the loop is closed by the jumpers/resistors.

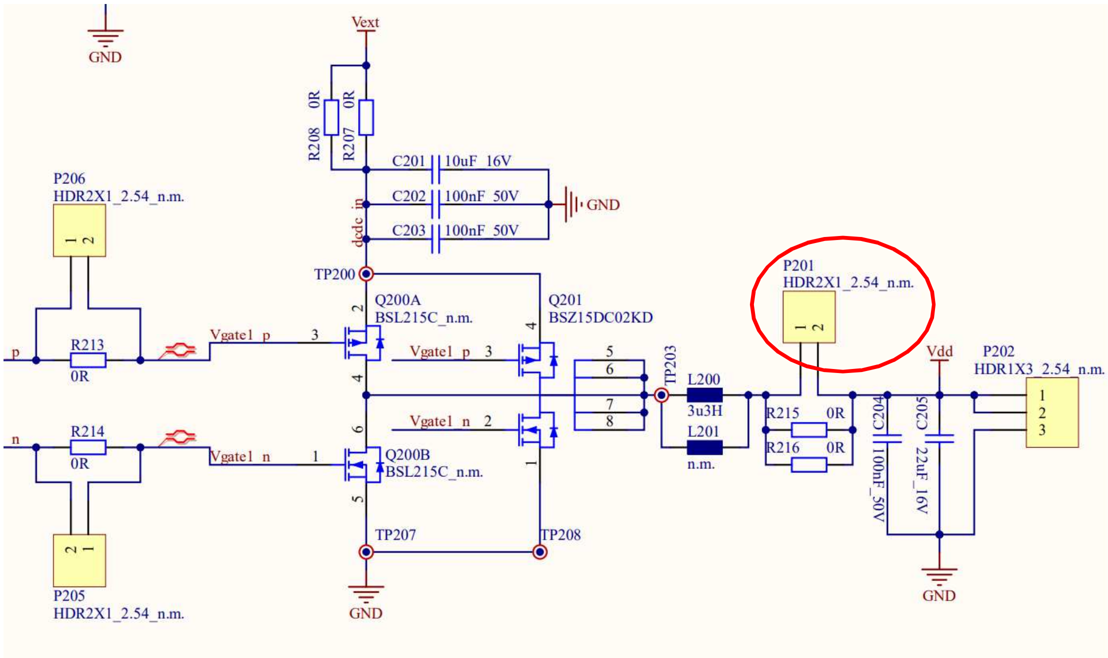
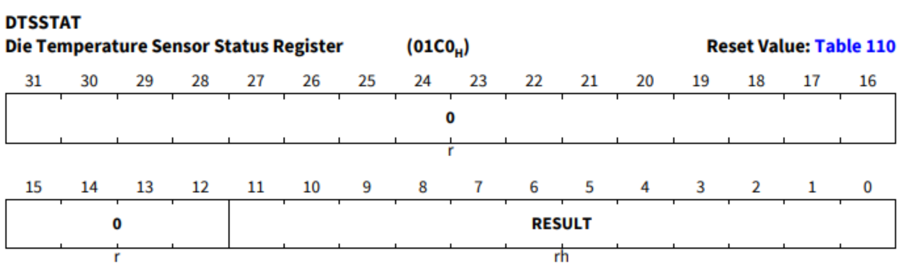


Figure 22 - EVRC Output schematics

- **Junction Temperature points: 150, 30, -40°C read from DTS**

  The temperature value is given as a 12-bit binary number on the register shown in Figure 23. The datasheet shows the address and how to make the conversion from the binary to °C.



Field	Bits	Type	Description
RESULT	11:0	rh	**Result of the DTS Measurement** This bit field shows the result of the DTS measurement. The value given is directly related to the die temperature and can be evaluated using the following formula. T (°C) = [RESULT / Gnom] - 273.15 T(°K)=[RESULT]/G_nom RESULT =G_nom * {T (°C) + 273.15} = G_nom * T (°K) G_nom = 7.505
0	31:12	r	**Reserved** Read as 0.

A thermostream is used to provide specified temperature values. The tolerance is about +-5°C. The setup with this equipment should be as sealed as possible to avoid energy loss.

- **VEXT supplied from 0V to 5V with slew rate = 10kV/s**

  To supply a specific slew rate, we can use a function generator and a power amplifier in pulse mode 5 to 0V, slew rate 10kV/s. Some function generators do not have the slew rate parameter, only the rising and falling time. The calculation is simple:

$$\mathrm{SR} = 10\,\frac{\mathrm{kV}}{\mathrm{s}}$$

$$\mathrm{SR} = \frac{\mathrm{Amplitude}}{RampTime}$$

$$RampTime = \frac{5}{10k} = 500\mu s$$

- **100 measures automated using TDEX**

  The function generator provides a pulse with a frequency. For each rising edge, one value is taken until the 100 values are collected.

- **Vthreshold = 2.97V**

  This parameter is the VEXT Threshold to the microcontroller reset. The default value is considered as the point where the MC's functions are not functioning anymore.

  The threshold for the low voltage reset can be configured in different levels but will always be set to its standard reset value when PORST is low, meaning that the microcontroller was reset.

  The following registers need to be changed to modify the threshold VEXT value:

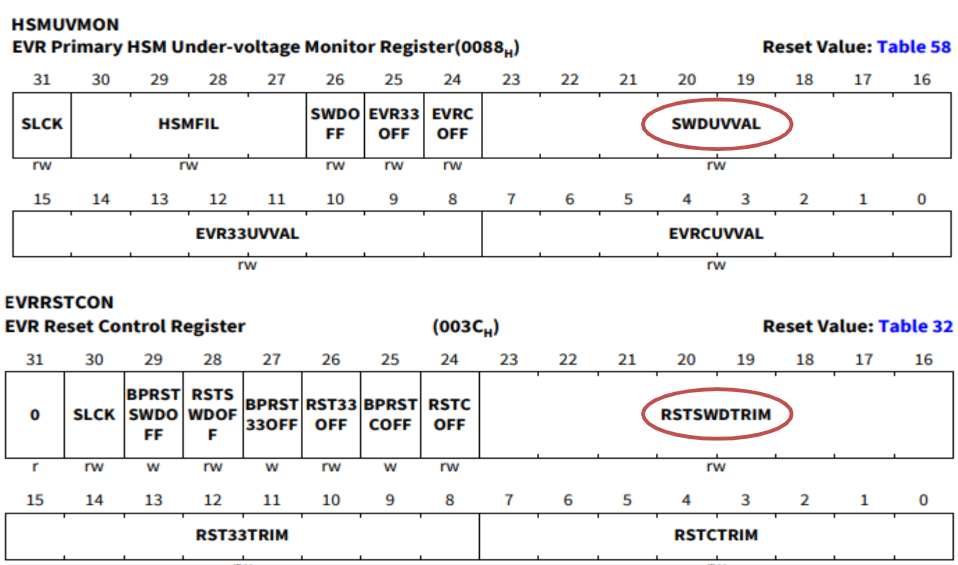


Figure 23 - Registers to change EVR trim level

- **Configure the oscilloscope to get the time measurement**

  The oscilloscope used inside the validation lab is precise and has several functionalities to be explored and used during the measurements.

  One of the Rhode&Schwarz scope measurement modes is called Delay to Trigger, which measures the time between the trigger point and an event.

  For this measurement, the VEXT trigger point is set to 2.97V. The event is configured as a falling edge of the PORST signal.

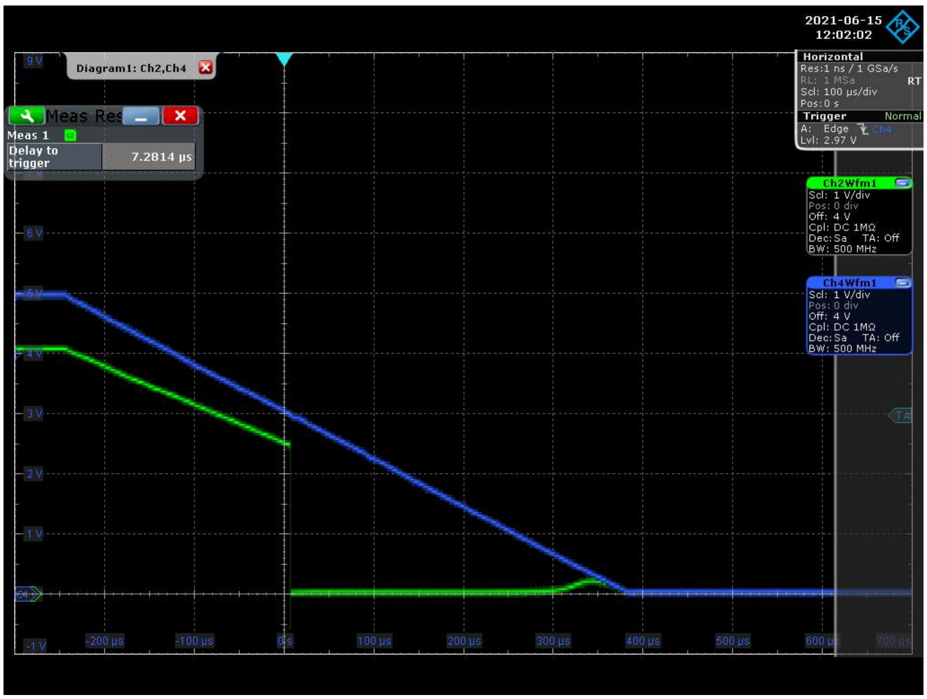


Figure 24 - Oscilloscope Screenshot - Time to PORST release

After getting all the values, the post-processing phase starts. The code generates a *.csv* file with all the measurement values listed inside. In this case, a boxplot was chosen to present the data to the project architects.

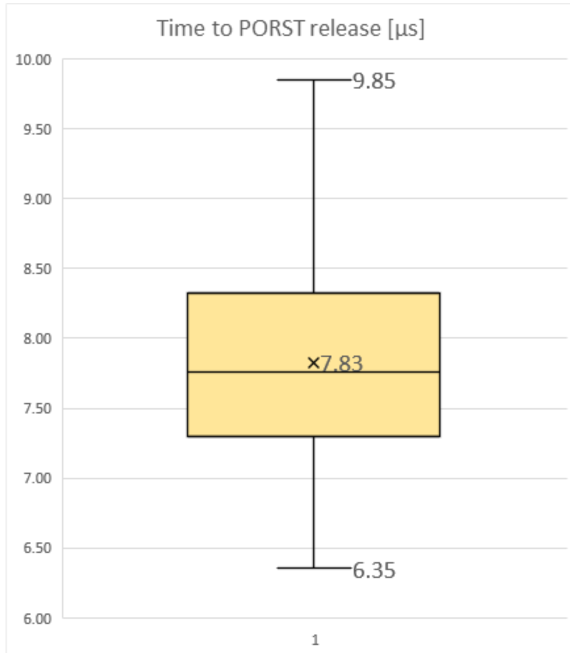


Figure 25 - Boxplot - Time to PORST release

For a hundred samples, the value was within 6.35 and 9.85 microseconds. The value expected was less or equal to 10µs. The parameter is validated.

3.4.3 PMS monitors - Preparation

The voltage monitors use dedicated ADCs that inform the MC of the actual voltage level. Different actions can be triggered by the monitors, from alarm flags inside the PMS and other Modules until the complete reset of the microcontroller.

Two types of ADC are presented below: Tracking ADC and SAR ADC.

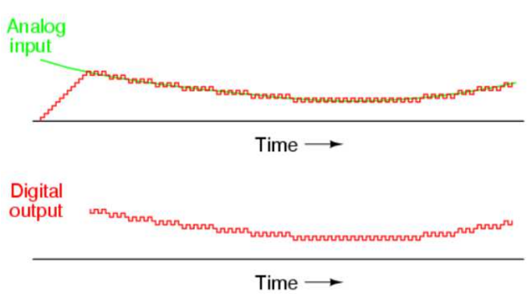


Figure 27 - Tracking ADC

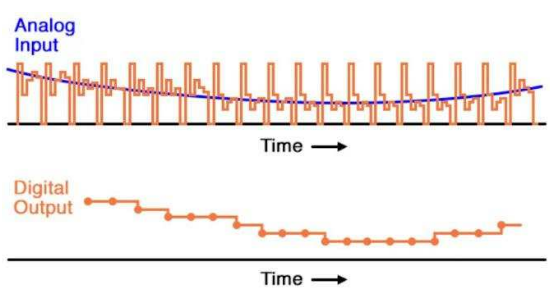


Figure 26 - SAR ADC

The tracking ADC can only do one LSB step per conversion, verifying for each iteration if the voltage is lower or higher than the voltage of the last step. The Successive approximation ADC changes the estimation most significant bit and compares this value with the input. If the voltage is lower, the bit returns to 0, and the next one turns into 1. The process repeats until the last bit, where the conversion value is given as the digital output and will be constant until the next conversion cycle.

Configuration:

1. **Power Mode A, VDD Supplied internally**

Depending on the supply levels, different power modes can be reached, each with pros and cons.

2. **User Mode**

   Some microcontroller registers are made for enabling more accessible validation of the DUT and are available only in the test mode phase. The validation group uses the user mode to simulate perfectly the customers' experience.

3. **Power up the DUT with nominal values**
4. **5v single supply source; EVRC active**
5. **Measure at RT**

   This specific measurement does not need an external Thermostream to change the DUT's temperature since the requirement is Room Temperature.

6. **HPBG active**

Measurement:

1. **Connect with the DUT and access the registers via UDE**

2. **Disable all primary monitors resets**

   Primary monitors resets are disabled to read registers even after detecting an over-voltage/under-voltage by the monitors. When the DUT resets, the registers are reset, and the monitor values are the default ones.

3. **Configure voltage threshold for OV detection → Primary and Secondary Monitors OV for each power domain**
4. **Enable the over-voltage alarm generation → Primary and Secondary Monitor Configuration – OV Enable**
5. **Configure voltage threshold for UV detection → Primary and Secondary Monitors UV for each power domain**
6. **Enable the under-voltage alarm generation → Primary and Secondary Monitor Configuration – UV Enable**

All of those configurations are made by changing registers. In total, there are more than 40 monitors, all stored in strings to make the automation easier and, if some of the registers are changed, they can be changed on the string declaration.

7. **Update the UV/OV value to the nominal supply value (e.g. 5V for VDDEXT) from the secondary monitors:**

   The objective is to increase/decrease the OV/UV value until the alarm flag goes high, avoiding changing the voltage on the power supplies and making the test much faster.

8. **For the primary monitors, the UV/OV values are kept as the standards.**

   To check the primary monitor functionality, it is vital to bring the threshold to the nominal value and bring up and down the supply level until the alarm goes high.

9. **Measure Vxx voltage on sense lines with a multimeter and store the data to crosscheck with monitors results.**

   More than ten rails need to be measured. Each monitor is associated with one rail. The multimeter measures only the rail that is related to the monitor under test to avoid unnecessary values on the table. The relation between multimeter, monitor, and rails is made through a class.

The measurement flowchart is in Annex 3.

This test sequence's code starts with the global variables' definition, files path, instrument instances, and monitor registers names. A class for the supply rails was created to store - among other methods – the information related to each of them.

```
public class ExternalRail
{
    public string name;
    public double voltage;
    public double currentLimit;
    public PowerSupply powerSupply;
    public string channel;
    public string[] options;

    public ExternalRail(string name, double voltage, double currentLimit, PowerSupply powerSupply, string channel)
    {
        this.name = name;
        this.voltage = voltage;
        this.currentLimit = currentLimit;
        this.powerSupply = powerSupply;
        this.channel = channel;
    }
}
```

In the initialization phase, the rails are created and associated with a power supply and a channel. If the same test sequence needs to be run in another setup, these are the only changes.

A function called void supplyMode(string *mode*) is used to configure the power supplies according to the mode chosen. The *mode* variable can be written on the test vector and directly called a parameter of this function, setting all the power supplies.

A dictionary was created to store the multimeter information. Because of the large supplies number to be measured, the multiplexer module is required, and the rails are associated with the supplies' name, information that will change for each execution.

On the initialization, the devices are connected through LAN, GPIB, and USB. TDEX provides all the libraries to establish the connection between the PC and the devices.

TDEX can store the register address and names to allow the programmer to call the register by name, keep a better track of the algorithm, and give flexibility if there is a mistake on the addresses.

Since all the information is stored on string arrays, the code is based on iterations of these arrays using the dedicated multimeter, power supply, and registers. The primary monitor's reset functionality is disabled, so the test can run without the PORST release, which means the chip does not reset and does not lose its register values.

The first execution case is about the primary monitors, in which the related power supply will have its value decreased/increased, moving away from the nominal value until the alarm is triggered. Values are stored and compared.

In the logic for the secondary monitors, the threshold will get closer to the nominal value of each iteration. If the alarm is set, the execution stops, the ADCs values are stored, and also the multimeter value.

The voltage levels need to be restored using the nominal value inside the rail object, and the alarms have to be reset before the next iteration.

3.5 Important tests – Overview

Power cycling :

The PMS has to support ramp-up/down for different timing, slew rates, and residual voltages for each supply rail. The PMS subsystem has to be robust in all different voltages ramp up and ramp down scenarios. We can see below the shape of the supplied rails.

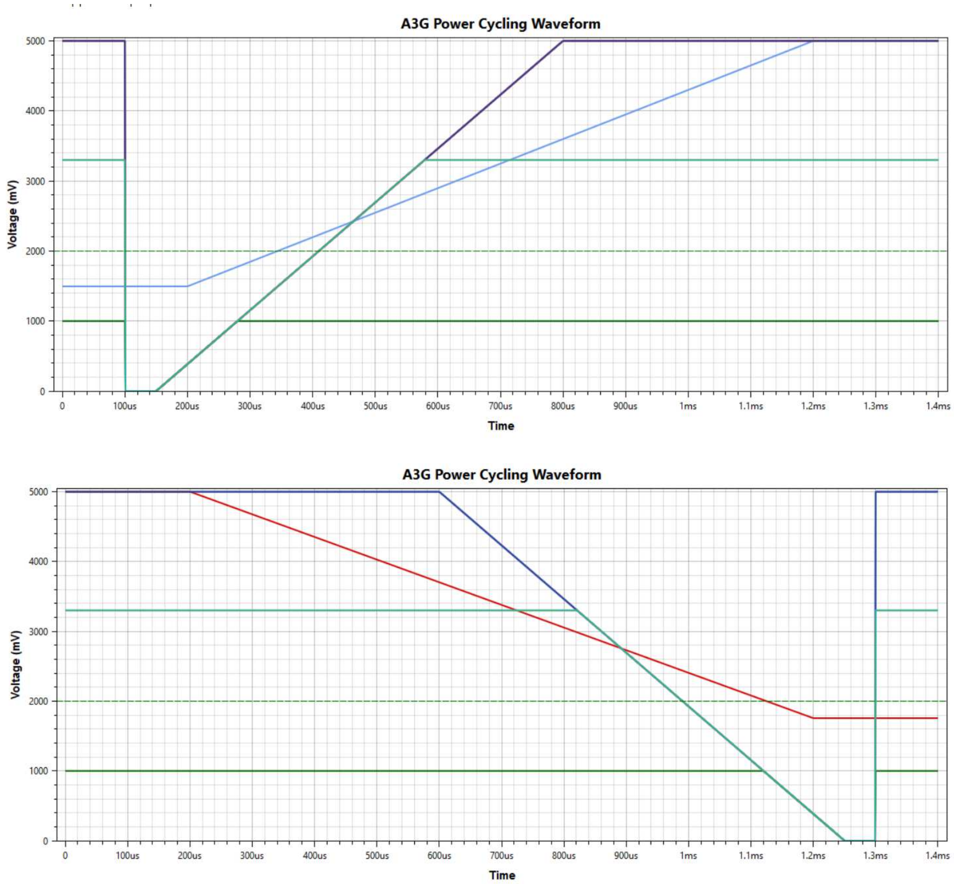


Figure 28 - Power Cycling curbs

This test is performed for all the temperature ranges, with a pace of 2°C, from -40 to 160.

EVRC Restart after Supply Fail:

The register settings of the internal core voltage regulator of the MCU shall be reset to their defaults if the V_{DD} voltage falls below a configurable low-voltage threshold.

This test aims to verify the reset of the registers after the chip resets and the behavior of the shown signals.

Figure 29 - EVRC Supply Fail

4 Validation Preparation

4.1 Bitbucket and JIRA

The ATV team uses the bitbucket software to upload all the project files and collaboratively develop our validation tasks. For the organization of the tasks, the software JIRA is used, where people involved in the project can create a JIRA ticket that will be tracked until the task is done. The validation requirements are also stored inside JIRA.

4.2 Validation Requirements

The validation requirements are functionalities/parameters of the chip that need to be checked on the validation process and are defined by system architects. Before writing the description and code of a test sequence, validation engineers align with architects on how the test should be performed, test points, and specific test details about the requirement in a DVS meeting.

4.3 Phases

The picture below gives an overview of the standard phases and milestones of a generic project. Every specific project type (IC, System, Software, etc.) implements its specific milestone definitions.

Standard phases:

- **Definition**: The product idea is selected from the roadmap to develop the customer & market requirements.
- **Implementation**: The product idea is developed from a concept into a product design.
- **Verification**: **& Validation**: Prove that the product meets specifications, works in the application and is producible.
- **Maintenance**: Optimized manufacturing

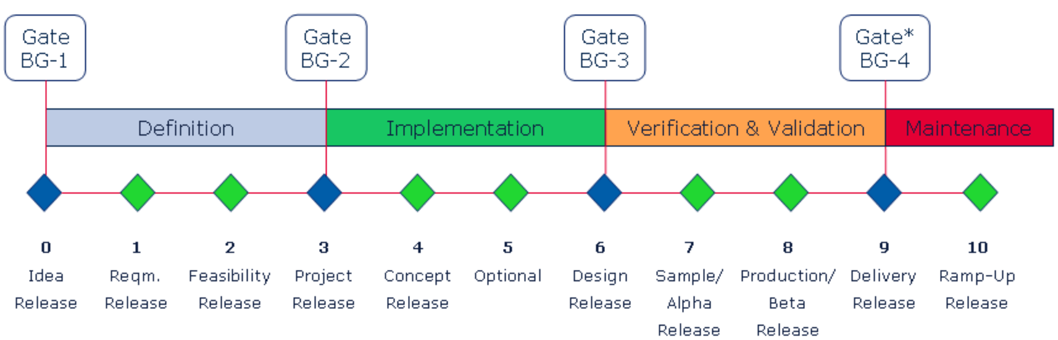


Figure 30 - Standard project phases

At Milestone 7, the chip gets on the hands of the validation engineers to perform the Bring-Up. A department called PTE is responsible for the first tests inside the production, with machines that have several coupled instruments to assure that the silicon has no defect.

The Bring-Up phase is where the most critical system-level tests are performed and have a short period of time to be finalized around 30 days. Long-term tests are also performed during this period as power cycling, which can take more than two weeks. The aim is to have a solid base to perform further tests. At the same time, the individual IPs validation is running, where all ADCs and other subsystems are individually verified.

Following this phase comes the normal validation cycle, in which all the test sequences are adapted, executed, and have their results presented with a pass or fail conclusion.

4.4 Automotive standards

The automotive department uses ISO 26262 and has an audit every year by an external company to verify if all the requirements are fulfilled. The ISO 26262, according to the International Organization of Standardization, is intended to be applied to safety-related systems that include one or more electrical and/or electronic (E/E) systems and that are installed in series production road vehicles, excluding mopeds.

5 Work at Infineon

5.1 Generic Training

The company proposes online internal training and needs to be completed within the first week of the internship.

Before the technical training starts, five mandatory training with questions and answers at the end are proposed:

- General safety information Villach
- Cyber & Information Security
- Data Protection
- Business Conduct Guidelines - Master Version
- Ergonomics at the Computer Workstations

After that, overview presentations of the A2G and A3G Microcontrollers were given to start the technical training.

5.2 First Month Tasks

During the first month of work, three validation tasks were proposed, and extensive documentation was also given as a guide, the internal target specification(ITS). They were all based on real measurement cases performed in the past, and the complexity level was higher with each one of the tasks.

A large amount of time was spent going through A2G ITS, which has information separate by modules, one of them being the PMS. The list of functionalities with technical descriptions and associated registers is inside this document, and it is imperative to start the validation tasks.

5.3 Meetings

Every week, there is a lab meeting to discuss technical subjects and administrative, organization, and bureaucratic topics.

The PMS team has a weekly meeting that aims to update the work and share useful information.

6 Soldering

The soldering station of the validation lab is often used to modify the circuit of the daughter boards, where all the components are SMD. Some tests need to be performed with different capacitances or resistances, simulating the real circuits where the MCs will be placed.

Some measurements put the chips into a stress condition, causing damage and making them unsuitable for further tests. Subsequently, these components are removed, and new ones are soldered.

Soldering an AURIX microcontroller is a delicate job, given that the pads are small and fragile. For the chips we have in the lab, the formats are the following:

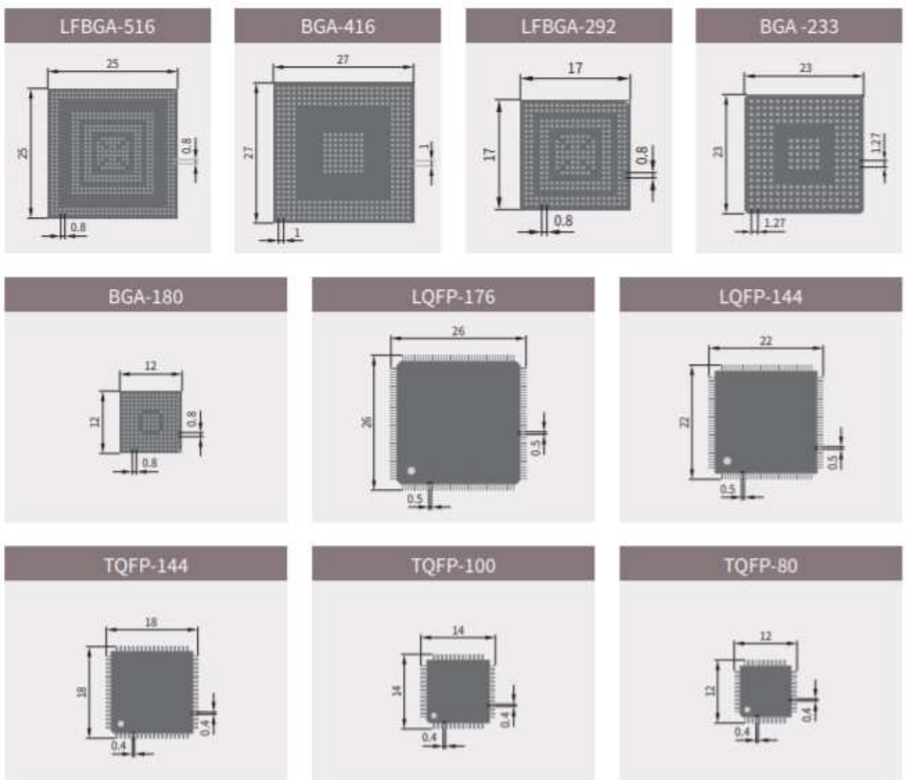


Figure 31 - Packages AURIX

When it comes to the BGA format, the soldering process is only possible using the oven. The first step is to clean the pads if they were already used using a solder wick and flux. The microcontroller comes already with soldering material and needs to the placed in the correct position, which is delimited by white lines on the Daughterboard PCBs. After choosing the right heat curb, the oven takes around 5 minutes to solder the components.

For the TQFP format, the process is the same, but the microcontroller pads are much more sensible and closer to each other and often need some adjustments after going into the oven.

7 Peltier

Aside from the validation tasks, a parallel task was proposed. The thermostreams already mentioned in section 3.2.6 are used to get high and low temperatures on the chip. The validation engineers were trying to find a way to optimize these processes since the area that needs to be refrigerated is approximately 5 cm², relatively small for the amount of power that the thermostreams consume. Another way to get to cold temperatures was proposed, using a thermoelectric solution: Peltier Modules.

This task aimed to build the first prototype to discuss the feasibility of this project forward.

A Peltier module consists of two external ceramic plates separated by semiconductor pellets.

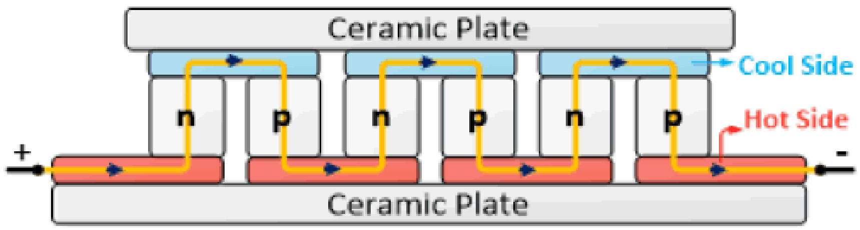


Figure 32 - Peltier Module

When polarized applying a voltage over the positive and negative poles, one of the two sides absorbs heat, and the other dissipates heat. The Peltier Modules cannot absorb thermal energy; its behavior is only based on thermal energy transfer from one side to another, requiring heat dissipation on the hot side if the aim is the lowest temperature on the cool side, as Figure 35 shows.

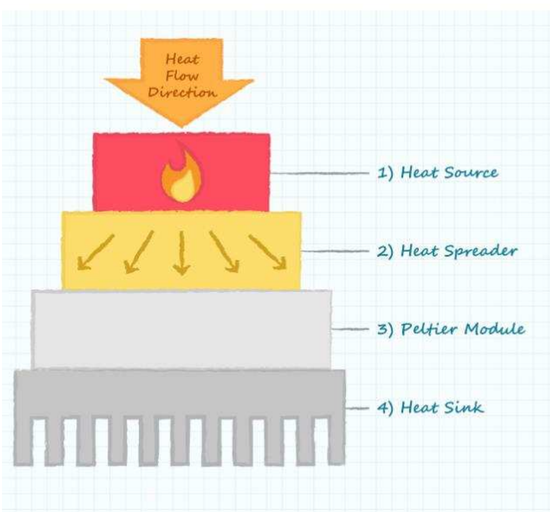


Figure 33 - Heat dissipation with Peltier Module

Figure 34 - Cascade Peltier Modules

Considering the size of the microcontrollers surface, a known solution with these modules in cascade formation (Figure 36) can bring the temperatures even lower, and this was the chosen approach.

For the prototype and tests, the material used was:

- Peltier TEC 40x40mm 8.5A
- Peltier TEC3 30x30mm 8.5A
- Peltier TEC 20x20mm 8.5A
- Thermal Paste
- CPU Cooler 100W
- Power supply four channels
- Thermometer

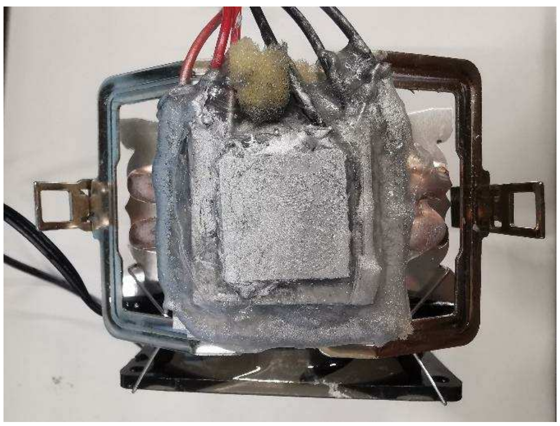


Figure 35 - Peltier modules fixed on heatsink

The prototype could bring the DTS-powered on-chip temperature to less than -23°C, and the viability of this project is still being discussed.

.

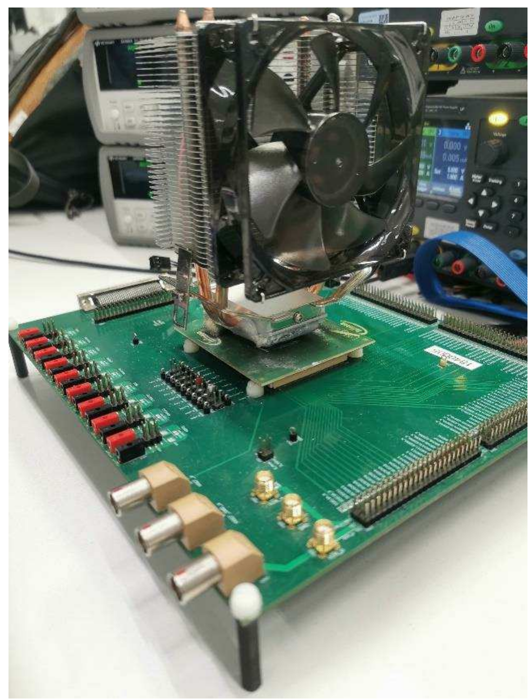


Figure 36 - Prototype MC Cooler

8 Conclusion

Being an intern at Infineon's validation laboratory was an exceptional experience. Working on a big project like the release of a Microcontroller involves a large amount of technical knowledge and time management, organizational and interpersonal skills.

The preparation was complete, all the test sequences assigned to me where coded and tested, approved by the supervisor. The algorithm behind test sequences was most of the time simple, the complexity is where to use which device and how to perform some of the measurements, more electronic and instrumentation focused.

Besides the fundamental electronic and programming knowledge, studying a specific product like the A2G and A3G Microcontrollers gives a practical comprehension of this module (PMS) and embedded functionalities that no University can teach.

Inside the validation laboratory, I had access to the most varied and expensive measurement equipment available in the market and mastered some of them by experimenting and searching for functionalities. Not only with the devices, I have used, but I feel familiarized with measurement devices in general, now able to use them confidently and efficiently.

It was also a great opportunity to extend my exchange program to one more country with a completely different culture. It adds a lot to my career to be in such a diversified group, where I worked directly with people from eight different countries, all of them inside the same validation lab. It was my first immersive English experience and my first contact with the German language, which is already on an intermediate level.

9 References

[1] **Infineon at a glance**
https://www.infineon.com/dgdl/INFIN+Flyer+About+Infineon+Update+EN_V14.pdf?fileId=5546d4614815da8801483b5ca7240434

[2] **Infineon Website – Our Divisions**
https://www.infineon.com/cms/en/about-infineon/company/our-divisions/

[3] **Road vehicles — Functional safety – ISO 26262**
https://www.iso.org/standard/68383.html

[4] **ESD from A to Z: Electrostatic Discharge Control for Electronics**

[5] **Infineon Website – Microcontroller**
https://www.infineon.com/cms/en/product/microcontroller/

[6] **XMC™ and AURIX™ – industrial microcontrollers portfolio**
https://www.infineon.com/dgdl/Infineon-AURIX_and_XMC_Industrial_Brochure-ProductBrochure-v01_00-EN.pdf?fileId=5546d462700c0ae60170a63d693f59a9

[7] **Introduction to Microcontrollers**
https://ti.tuwien.ac.at/ecs/teaching/courses/mclu/theory-material/Microcontroller.pdf

[8] **Git - Getting Started - What is Git?**
https://git-scm.com/book/en/v2/Getting-Started-What-is-Git%3F

[9] **How to Select a Peltier Module**
https://www.cuidevices.com/blog/how-to-select-a-peltier-module#peltier-module-basics

[10] **Description & Modeling of Cascade Thermoelectric Modules**
https://thermal.ferrotec.com/technology/thermoelectric-reference-guide/thermalref12/

[11] **Four-wire resistance measurements**
http://lampx.tugraz.at/~hadley/semi/ch9/measurements/4pt/4pt.php

[12] **AURIX™ 32-bit microcontrollers for automotive and industrial applications**
https://www.infineon.com/dgdl/Infineon-TriCore_Family_BR-ProductBrochure-v01_00-EN.pdf?fileId=5546d4625d5945ed015dc81f47b436c7

10 Annexes

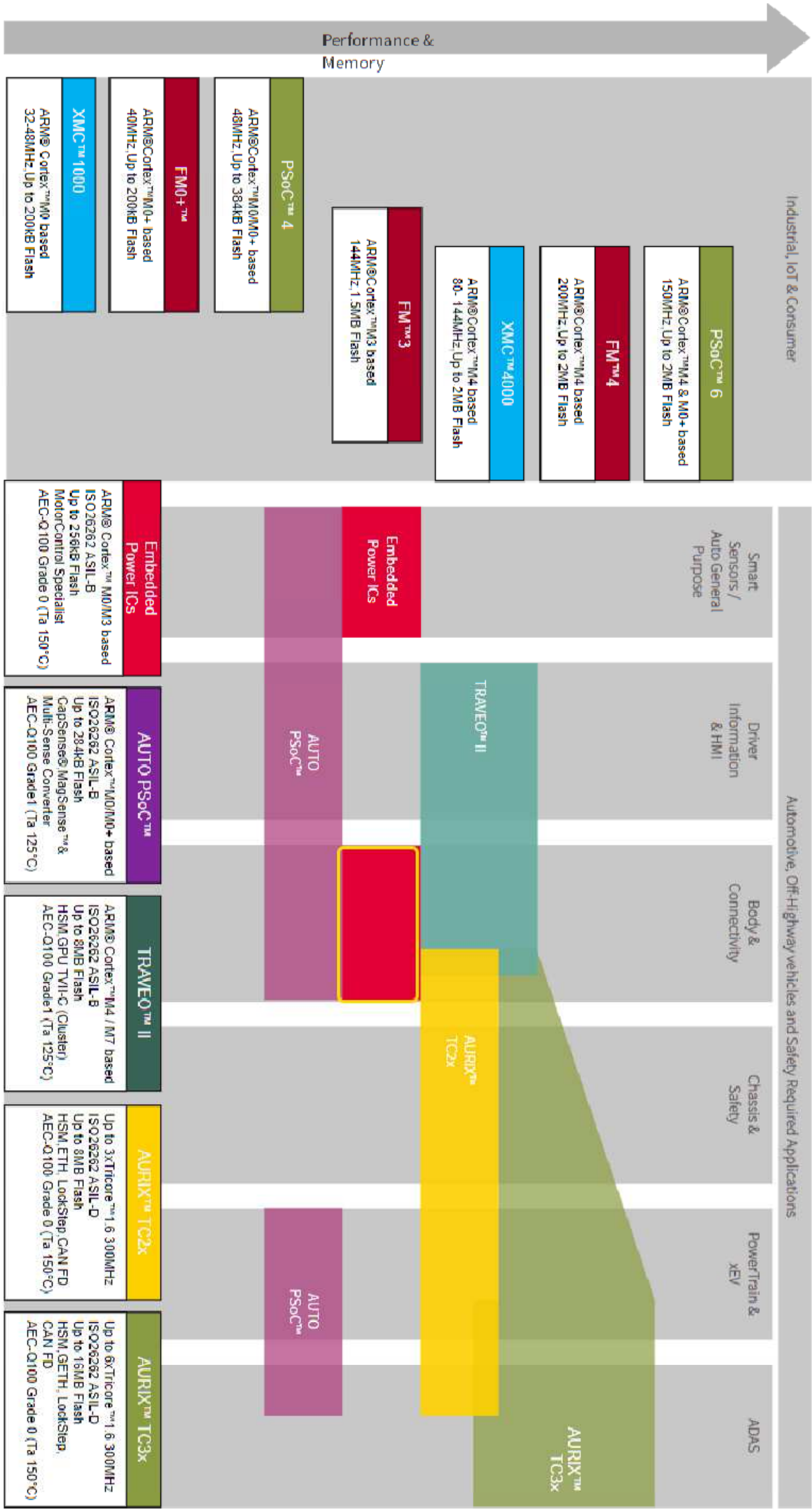
Annex 1: Application Microcontroller Models

Annex 2: Packages and Models A2G Microcontrollers

Annex 3: Flowchart PMS Monitors Test Sequence

Annex 4: Ramp-Up / Ramp-Down of supply mode A – A2G

Annex 1: Application Microcontroller Models

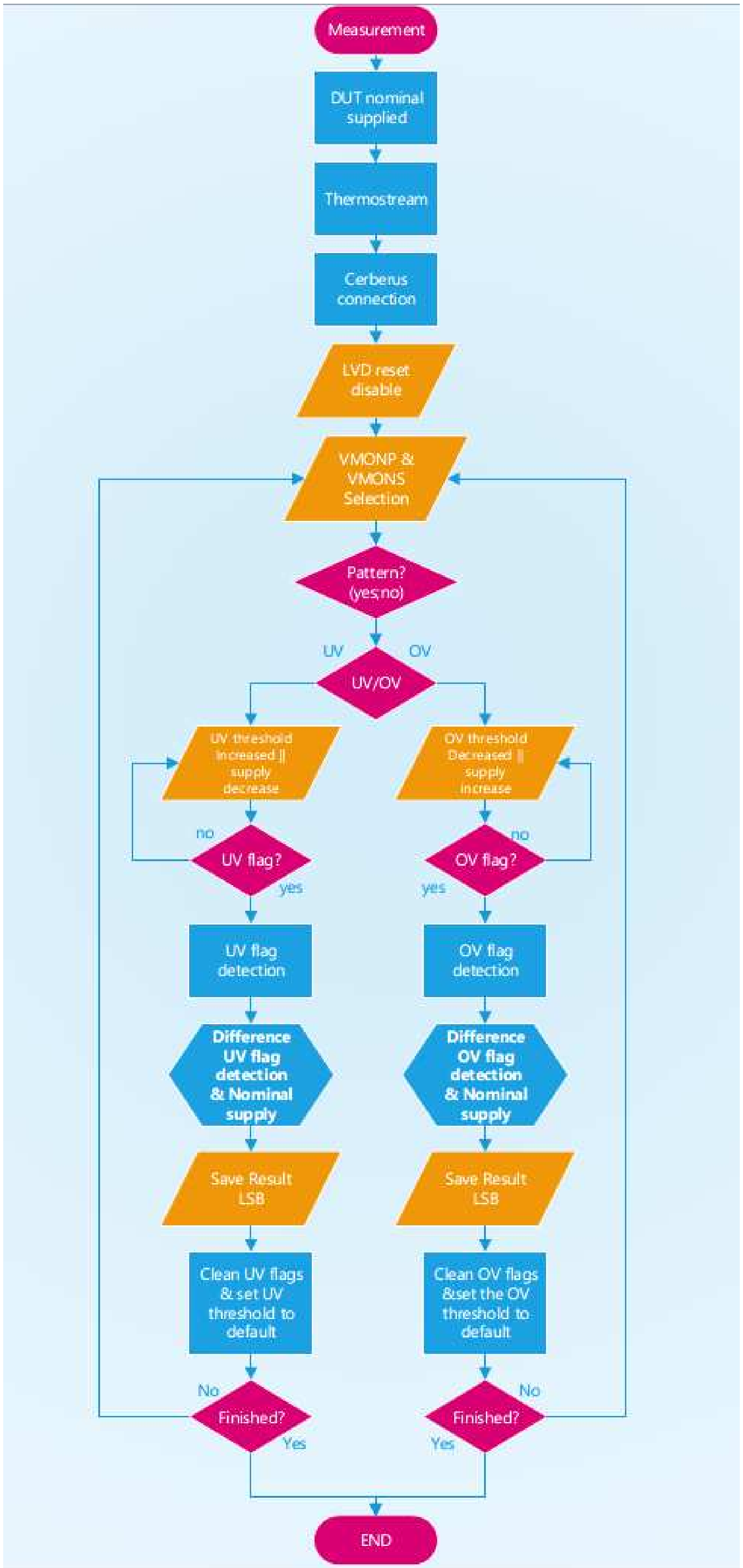


Annex 2: Packages and Models A2G Microcontrollers

Control & Actuate
Sense & Compute

Flash	Package	TQFP-80	TQFP-100	T/LQFP-144	BGA-180	LQFP-176	BGA-216	LFBGA-292	LFBGA-516
6x 300 MHz	9xA Series 16 MB							TC397XA 300 MHz	
6x 300 MHz	9x Series 16 MB							TC397X 300 MHz	TC399X 300 MHz
4x 300 MHz	Ex Series 12 MB							TC3E7Q 300 MHz	
4x 300 MHz	8x Series 10 MB							TC387Q 300 MHz	TC389Q 300 MHz
3x 300 MHz	7xX Series 6 MB							TC377TX 300 MHz	
3x 300 MHz	7x Series 6 MB					TC375T 300 MHz		TC377T 300 MHz	
2x 300 MHz	6x Series 4 MB			TC364D 300 MHz	TC366D 300 MHz	TC365D 300 MHz		TC367D 300 MHz	
3x 300 MHz	5xA Series 4 MB				TC356TA 300 MHz			TC357TA 300 MHz	
2x 300 MHz	3xA Series 2 MB				TC336DA 300 MHz			TC337DA 300 MHz	
1x 200 MHz *	3x Series 2 MB	TC332L 200MHz *	TC333L 200MHz *	TC334L 200 MHz *	TC336L 200 MHz *			TC337L 200 MHz *	
1x 160 MHz	2x Series 1 MB	TC322L 160 MHz	TC323L 160 MHz	TC324L 160 MHz				TC327L 160 MHz	

Annex 3: Flowchart PMS Monitors Test Sequence



Annex 4: Ramp-Up / Ramp-Down of supply mode A – A2G

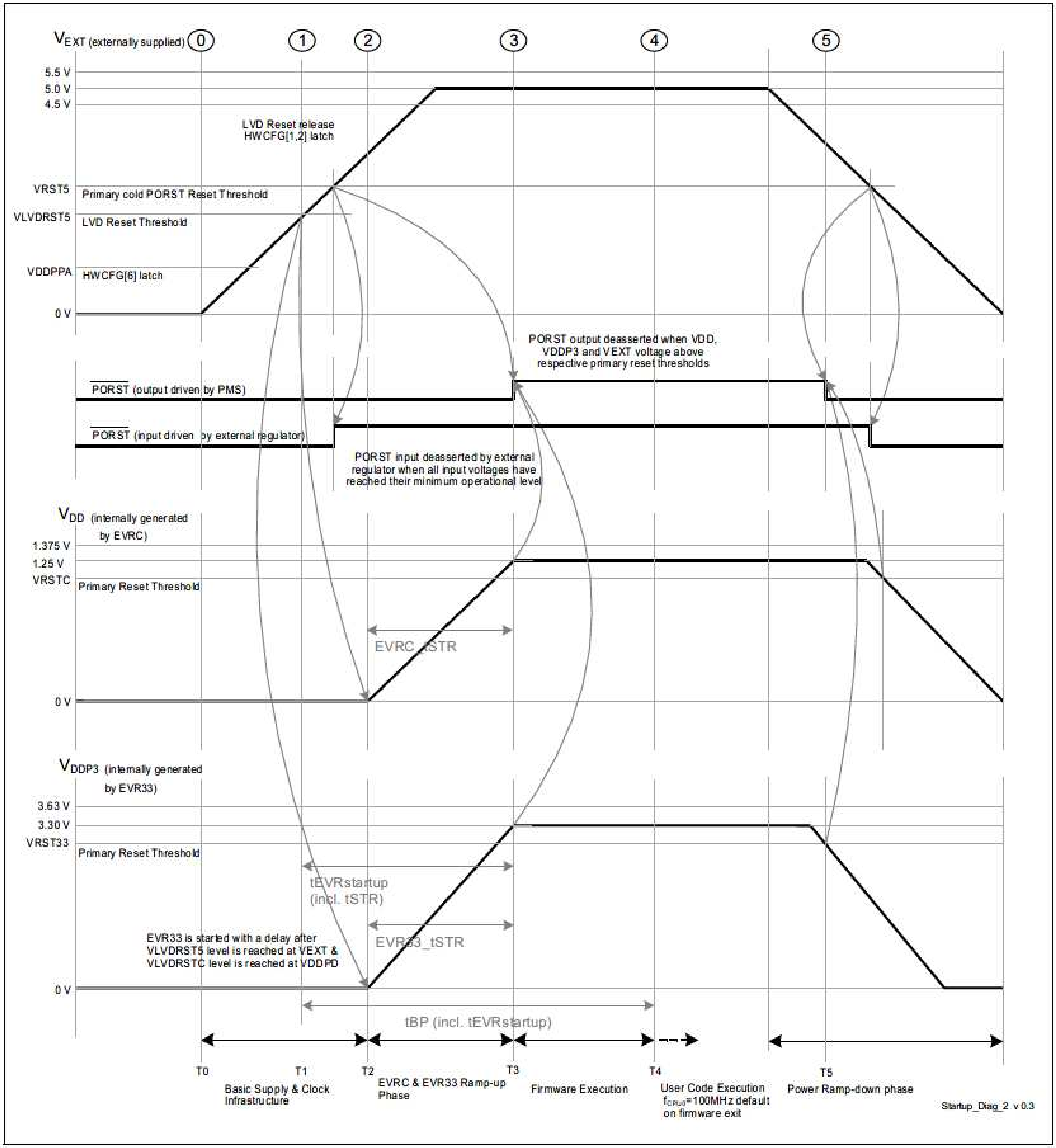


Figure 3-3 Single Supply mode (a) - V_{EXT} (5 V) single supply