Design Electricity Meters with Kinetis M Series MCUs

FTF-SEG-F0469

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Session Objectives

• Understand electricity meter block diagram and major functionalities
• Familiarize with Kinetis M series MCUs
• Become familiar with Freescale electricity meter reference designs, HW/SW development tools and algorithms offering
• Mastering MCU programming…

Tutorial

• Ideal Hilbert Transformer

Kinetis M series products are designed for next-generation smart meter applications. The cost-effective Kinetis M series MCUs combine a sophisticated analog front end (AFE), hardware tamper detection and low-power operation to enable the design of secure, high-accuracy 1-, 2- and 3-phase electricity metering solutions. Freescale also provides proven 1-, 2-, and 3-phase hardware reference designs with complex metrology firmware satisfying 0.1% measurement accuracy and all ESD requirements. Traditional smart metering designs typically employ two chips to separate user billing software from the main application code, as required by WELMEC, OIML and other global standards. However, Kinetis M series MCUs handle this task with a single chip due to their on-chip memory protection unit, peripheral bridge, protected GPIO and DMA controller. To guard against external tampering, M series MCUs include active and passive tamper pins with automatic time stamping throughout, including on the independent real-time clock (iRTC). In addition, a random number generator enables faster, easier implementation of encryption algorithms than software implementations…

Introduction to Electricity Metering

- Kinetis M Series MCUs
- Electricity Metering Algorithms
- Electricity Meter Reference Designs
- Kinetis M Development Tools
- Mastering MCU Programming…
- References
• **Measure**
  - Electricity meters must measure phase voltages and phase currents consumed by connected load.
  - Measurement linearity of 0.1% over 2000:1 dynamic range.
  - Shunt resistors, current transformers or Rogowski coils can be connected.

• **Process**
  - Accurate calculation of the active and reactive energies.
  - Time keeping with accuracy better than ±0.5s/day needed for billing purposes.
  - Tamper processing ensures security.
  - Load profiles and parameters storage.

• **Display**
  - LCD display allows visual inspection.
  - HMI (control button) allows system configuration.
  - IR / RF communication allows download of data for utility companies and automatic meter reading.
Agenda

- Introduction to electricity metering
- Kinetis M series MCUs
  - Electricity metering algorithms
  - Electricity meter reference designs
  - Kinetis M development tools
  - Mastering MCU programming…
- References
Core
• CM0+ core Up to 50MHz
• CM0+ core Up to 50MHz
• Separate FLL post-scalers for Flash and Core clocks.
• Dedicated PLL for ΣΔ modulator clock
• 4ch DMA
• Memory Protection Unit
• Single 32kHz Crystal operation
• MHz Crystal optional

Security & Encryption
• Programmable 16/32-bit CRC
• IRTC w/ tamper detection
• 3 Tamper pins (operating on battery)
• Random Number Generator (NIST: SP800-90)
• AES Encryption (via software library)
• Memories
• Up to 128 KB Program Flash
• 16 KB SRAM

Analog
• 4x24 bit ΣΔ after averaging (2xPGA) highly accurate supporting EN 50470-1, EN 50470-3, IEC 62053-21, IEC 62053-22 and IEC 62053-23, optimized for shunt sensor (≥50uOhm).
• 0.1% error in active and reactive energy over a dynamic range of 2000 to 1
• Internal 1.2V reference voltage (33 ppm/°C)
• 12-ch 16-bit SAR for auxiliary measurement
• 2x analog comparator

Serial Communications
• 2x SPI
• 4x UART
• All combined with Quad Timer & HSCMP for IR
• 2 support ISO7816
• All support flow control
• 2 × I2C
• All UARTs and SPIs are 3V compatible while 1 UART and 1 SPI are both 3V and 5V compatible (open drain configuration)

Peripheral XBAR
• Remapping peripheral I/Os
• UART selection for IR

Timer/PWM/Clock
• Quad Timer (total 4 universal timers)
• 2x PIT
• 1x Watchdog Timer (windowed, independently clocked)
• 1x EWM (External Watchdog Monitor)
• 1x LPTimer

LCD Display
• Up to 288 segment LCD, up to 8 backplanes

Wakeup Unit
• Group selected GPIOs (16), LPTIM, RTC (+tamper pins), HSCMP, SCI, Brownout and POR sources to wake up from Power Gated STOP mode

GPIO
• Up to 68 with push pull, pull up/down select
• Up to 8 GPIO with filter
• Support for interruption on any edge
• Single cycle access for all GPIOs (Rapid GPIO)

Power Modes & Clock
• Many low power modes supported
• 2.7V to 3.6V Operating voltage with AFE
• 1.71V to 3.6V Operating voltage without AFE
• 1.71V-3.6V IRTC VBAT supply
• 32kHz or 4 MHz internal clock source
• 32.768kHz crystal oscillator

Package
• 100 LQFP, 64 LQFP and 44 LGA options
• -40°C ~ +85°C Temp

**IPs with functionality specific to metering**

+/-250mV analogue I/O pads with 6kV PESD
Analogue Subsystem (Overview)

1.2V Voltage Reference
- Generates accurate reference voltage shared between PGA, SD ADC, SAR ADC and HSCMP

16-bit SAR ADC
- Conversion speed up to 818 ksps
- 12 single ended channels
- 4 result registers
- Variety of triggering options

24-bit SD ADC and PGA
- Conversion speed up to 101 ksps on four channels
- Four SD ADC channels (two PGA)
- SW and HW triggering

High-Speed Comparator
- Two comparators, each with
- 6-bit DAC to provide selectable voltage reference
- Accepts a +/-250mV input signal range

Inter-peripheral Crossbar Switch
- Allows programmable digital interconnections between specific modules
- 33 input x 33 output multiplexer
- Interrupt or DMA request

Phase Shifter and Decimator
- Phase shift compensation with resolution of 0.003° @ 50 Hz line frequency
- Capability to connect external galvanic ally isolated SD modulators

Kinetis M analogue and digital blocks allow realization most of electricity meter use-cases.
Analogue Subsystem (Electricity Meter Use-Cases)

• 1-Phase

- All measurements performed by SD ADC
- Shunt resistor measurements amplified by Programmable Gain Amplifier (PGA)
- Phase shift between phase voltage and phase current measurements compensated by Phase Shifter block.

Kinetis M

<table>
<thead>
<tr>
<th>ADC11</th>
<th>ADC2</th>
<th>ADC1</th>
<th>ADC0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA+SD</td>
<td>1.2V VREF</td>
<td>2x HSCMP</td>
<td>16-bit SAR ADC</td>
</tr>
<tr>
<td>MUX</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kinetis M

1-Phase with neutral current measurement

<table>
<thead>
<tr>
<th>ADC11</th>
<th>ADC2</th>
<th>ADC1</th>
<th>ADC0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA+SD</td>
<td>1.2V VREF</td>
<td>2x HSCMP</td>
<td>16-bit SAR ADC</td>
</tr>
<tr>
<td>MUX</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

freescale™
Analogue Subsystem (Electricity Meter Use-Cases – Cont’d)

- **Form-12S**

  - All measurements performed by SD ADC
  - Rogowski coil measurement optionally amplified by Programmable Gain Amplifier (PGA)
  - Phase shift between phase voltage and phase current measurements compensated by Phase Shifter block.

- **3-Phase with neutral current measurement**

  - Phase and neutral current measurement performed by SD ADC
  - Phase voltage measurement performed by 16-bit SAR ADC
  - Phase shift between phase voltage and phase current measurements compensated either numerically a FIR filter or by hardware using Quad Timer channels.
Analogue Subsystem (SD ADC and PGA)

- **Blocks**
  - Four channels with 24-bit SD ADC (two PGAs)
  - Phase Shifter & Decimator
  - CPU/DMA Interface

- **Electrical parameters**
  - Full operating voltage range: 2.7V to 3.6V
  - \(\pm 250\) mV (1 V\(_{\text{P-P}}\) differential, 0.5 V\(_{\text{P-P}}\) single ended) input range for both single ended and differential inputs
  - Common mode voltage range of 0 to 0.8V
  - SD modulator Signal-to-Noise Ratio:
    - Normal mode: 92dB @ (Fs=6.144MHz, OSR=2048)
    - Low power mode: 82dB @ (Fs=0.768MHz, OSR=256)

- **Features**
  - Supports single and continuous conversions
  - Support both software and hardware triggering
  - Output sampling rates: 3 kHz, 6 kHz, 12 kHz, 24 kHz, 48 kHz, and 96 kHz
  - Gain programmable from 1x to 32x
  - Dynamic phase shift compensation
  - Synchronized start operation
  - Option to generate interrupt or DMA request on conversion complete

- **SD ADC measurement range**

<table>
<thead>
<tr>
<th>Operation Mode</th>
<th>PGA</th>
<th>Signal range (mV peak-peak)</th>
<th>SNR (dB @ OSR=2048)</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>ON</td>
<td>31 (gainx32)</td>
<td>64 (74)</td>
<td>4.0</td>
</tr>
<tr>
<td>Low Power</td>
<td>ON</td>
<td>31 (gainx32)</td>
<td>52 (62)</td>
<td>3.1</td>
</tr>
<tr>
<td>Normal</td>
<td>OFF</td>
<td>1000</td>
<td>92</td>
<td>1.4</td>
</tr>
<tr>
<td>Low Power</td>
<td>OFF</td>
<td>1000</td>
<td>82</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Register bits</th>
<th>Single channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single channel</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VLPR</th>
<th>VLPW</th>
<th>STOP</th>
<th>VLPS</th>
<th>VLLSx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>FF</td>
<td>STOP</td>
<td>FF</td>
<td>OFF</td>
</tr>
<tr>
<td>(PLL disabled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analogue Subsystem (16-bit SAR ADC)

- **Blocks**
  - Single 16-bit SAR ADC
  - Four result registers allows measurement up to four samples without interrupt service
  - Selectable voltage reference: SAR_VDDA, 1.0V bandgap from PMC, 1.2V VREF (from off-chip or internal source)

- **Features**
  - Output Modes: single-ended 16-bit, 12-bit, 10-bit and 8-bit modes
  - Output in right-justified unsigned format for single-ended
  - Single or continuous conversion (automatic return to idle after single conversion)
  - Configurable sample time and conversion speed/power
  - Input clock selectable from up to four sources
  - Programmable operation in some low-power modes for lower noise operation
  - Asynchronous clock source for lower noise operation with option to output the clock
  - Selectable asynchronous hardware conversion trigger with hardware channel select
  - Automatic compare with interrupt for less-than, greater-than or equal-to, within range, or out-of-range, programmable value
  - Temperature sensor
  - Conversion rate up to 818ksps (≤12-bit mode)
  - Hardware average function
  - Self-Calibration mode

<table>
<thead>
<tr>
<th>VLPR</th>
<th>VLPW</th>
<th>STOP</th>
<th>VLPS</th>
<th>VLLSx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>FF</td>
<td>FF</td>
<td>(ADC internal clock only)</td>
<td>OFF</td>
</tr>
</tbody>
</table>
### Analogue Subsystem (High-speed Comparator)

#### Blocks
- Two comparators
- Up to six external inputs and internal 6-bit DAC reference.
- Selectable voltage reference: VDD or 1.2V VREF (from off-chip or internal source)

#### Features
- CMP1 can accept a +/-250mV input with input common-mode voltage: 0 to 0.8V for both single ended and differential channels
- Continuous and sampled modes
- Programmable filter and hysteresis (5 .. 30 mV)
- Propagation delay from 20ns (high speed mode)
- CMP and 6-bit DAC sub-block supports trigger mode operation by LPTMR. Trigger sequence enables the CMP and DAC prior to performing compare and capturing the output

#### Signal assignments

<table>
<thead>
<tr>
<th>CMP Signals</th>
<th>CMP0</th>
<th>CMP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP Input0</td>
<td>PTD0/CMP0P0/PXBAR_IN2/LLWU_P11/SCI0_SCL/RxD</td>
<td>PTB6/CMP1P0/LCD37</td>
</tr>
<tr>
<td>CMP Input1</td>
<td>PTD2/CMP0P1/PXBAR_IN1/LLWU_P10/SPI0_SCK/SCI1_RxD</td>
<td>PTC1/CMP1P1/LCD40/SCB4_CTS</td>
</tr>
<tr>
<td>CMP Input2</td>
<td>PTD5/CMP0P2/PXBAR_IN5/LLWU_P8/SPI1_SCK/SCI2_SCL/SCI2_RxD</td>
<td>SDADP2/CMP1P2</td>
</tr>
<tr>
<td>CMP Input3</td>
<td>PTC3/CMP0P3/LLWU_P13/LCD42/SCB3_RxD</td>
<td>SDADP3/CMP1P3</td>
</tr>
<tr>
<td>CMP Input4</td>
<td>PTD7/CMP0P4/PXBAR_IN4/LLWU_P7/SPI0_SCL/SCI3_RxD</td>
<td>SDADP3/CMP1P3</td>
</tr>
<tr>
<td>CMP Input5</td>
<td>PTC5/CMP0P5/PXBAR_IN8/PHIO_IN/SCI1_MOSI/SCI1_MISO/SCI1_RxD</td>
<td>SDADP3/CMP1P3</td>
</tr>
<tr>
<td>CMP Input6</td>
<td>Reserved</td>
<td>Reserved</td>
</tr>
<tr>
<td>CMP Input7</td>
<td>6-bit DAC reference</td>
<td>6-bit DAC reference</td>
</tr>
<tr>
<td>CMP Output0</td>
<td>PTA5/CMP0OUT/LLWU_P14/LCD29</td>
<td>PTD6/AD4/CMP1OUT/SCI1_MISO/SCI1_RTS</td>
</tr>
<tr>
<td>CMP Output1</td>
<td>PTE5/CMP0OUT/LLWU_P7/SPI0_Tx/EBM_OUT</td>
<td>PTF2/CMP1OUT/LPTIM2/LLWU_PS/Rx/LCD2</td>
</tr>
</tbody>
</table>

1) High-Speed Comparison mode
2) Low-Speed Comparison mode
3) OFF in VLLS0
Analog Subsystem (1.2V Voltage Reference)

- **Features**
  - Option to use internal or external voltage reference source
  - Generates accurate reference voltage shared between 24-bit SD ADCs, PGAs, 16-bit SAR ADC, and CMPs
  - Generates 1.2V and 0.4V voltages
  - Low VREF gain drift over temperature of 33 ppm/°C (typ.)
  - Programmable trim register with 0.5 mV steps
  - Programmable mode of operation
    - Off
    - Bandgap enabled/standby (output buffer disabled)
    - Low power buffer mode (output buffer enabled)
    - High power buffer mode (output buffer enabled)

- **Reference control switches**

<table>
<thead>
<tr>
<th>Switch Position</th>
<th>16-bit SAR ADC Reference</th>
<th>6-bit DAC (CMP) Reference</th>
<th>24-bit SD ADC and PGA Reference</th>
<th>VREF Pin Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S0</td>
</tr>
<tr>
<td>UP</td>
<td>ON</td>
<td>DOWN</td>
<td>DOWN</td>
<td>3.3V SAR_VDDA</td>
</tr>
<tr>
<td>UP</td>
<td>OFF</td>
<td>DOWN</td>
<td>DOWN</td>
<td>3.3V SAR_VDDA</td>
</tr>
<tr>
<td>DOWN</td>
<td>ON</td>
<td>DOWN</td>
<td>DOWN</td>
<td>1.2V VREF Internal</td>
</tr>
<tr>
<td>DOWN</td>
<td>OFF</td>
<td>DOWN</td>
<td>DOWN</td>
<td>1.2V VREF Internal</td>
</tr>
<tr>
<td>UP</td>
<td>OFF</td>
<td>DOWN</td>
<td>UP</td>
<td>3.3V SAR_VDDA</td>
</tr>
<tr>
<td>UP</td>
<td>OFF</td>
<td>UP</td>
<td>DOWN</td>
<td>3.3V SAR_VDDA</td>
</tr>
<tr>
<td>DOWN</td>
<td>OFF</td>
<td>UP</td>
<td>UP</td>
<td>1.2V VREF External</td>
</tr>
</tbody>
</table>

Switch S1 is meant for outputting 1.2V VREF on the device pin. When using externally supplied VREF, this switch should be open.
Analogue Subsystem (Peripheral Crossbar)

- **Features**
  - Allows programmable interconnection between specific device modules
  - 33 input x 33 output multiplexer
  - Any input can be connected to any output
  - Edge detection with associated interrupt or DMA request generation for one output (XBAR_OUT0)

- **Application use-cases**
  - SCI baud rate detection
  - Monitoring internal signals
  - Interfacing external SD modulators
  - Triggering of SAR & SD ADC conversions
  - IR communication support
  - RTC Clock correction
  - Supplying external signals to peripherals

### Table: VLPR, VLPW, STOP, VLPS, VLLSx

<table>
<thead>
<tr>
<th>VLPR</th>
<th>VLPW</th>
<th>STOP</th>
<th>VLPS</th>
<th>VLLSx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td></td>
<td>Static</td>
<td>Static</td>
<td>OFF</td>
</tr>
</tbody>
</table>

*Static (configured signal paths are fully functional but register states are retained)*
Code Separation Technique in Metrology Applications

- **Legally relevant** software shall run in privileged mode exclusively preventing other software functions to influence its execution.
- Memory sections for **legally relevant** software, parameters and variables storage shall be protected against reading, writing and execution (R/W/E) from other software routines.
- On-chip peripherals controlled by the **legally relevant** software shall not be influenced by other software routines.

**Traditional ways of maintaining code separation → two chip solution:**

**Literature:**
Kinetis M Series MCUs - Single Chip Solution

- **Kinetis M platform** supports access permissions for privileged secure, user secure and user non-secure mode. These permission attributes can be either forced on a per bus master basis or inherited from the reference.
- Read, write and execute accesses to on-chip memories are protected by the **Memory Protection Unit (MPU)**.
- Read and write accesses to on-chip peripherals are handled by **Peripheral Bridge (AIPS-Lite)**. GPIO pins can also be accessed via the core’s fast IOPORT (private bus supporting 1-cycle loads and stores).

More details on the next slide…
Kinetis M Series MCUs – Legally Relevant/Non-relevant Software Separation HW Support

**Memory Protection Unit (MPU)**
Performs on-chip memory access control based on access attributes of each bus cycle. Separate access rights can be defined for “CM0+” and “DMA” bus masters.

**Peripheral Bridge (AIPS-Lite)**
Performs on-chip peripheral register space access control based on access attributes of each bus cycle.

**DMA Controller Module**
Conducts accesses to on-chip memory with either fixed or inherited access attributes. Supports privileged secure and user secure/non-secure access modes on a per channel basis.

**Miscellaneous Control Module (MCM)**
Forces and enables control attributes for “CM0+” and “DMA” masters. Supports privileged secure and user secure/non-secure access modes.

**Kinetis M Platform**
Supports privileged and user access modes.

**GPIO Protection**
Controls R/W accesses to GPIO pins (grouped to 8-bit ports). Supports privileged secure and user secure/non-secure access modes based on access attributes of each bus cycle.

*The processor core supports privileged and user modes of execution. The platform adds the concepts of a processID register that supports the 3-state privilege model: privileged, user secure, user non-secure.*
Segment LCD Controller

- **Segment fault detection capability**
  - Hardware support for segment LCD display errors

- **Up to by 8 multiplexing**
  - Fewer pins required to drive LCD segments
    - Up to 40 front plane signals (up to 4x40)
    - Up to 8 back planes signals (up to 8x36)

- **Low power blinking mode**
  - LCD glass blink capability in low power modes
  - Alternate display feature can be activated to display alternate data (i.e. blink flow in m³ and time)

- **Front and back plane re-assignment**
  - Any LCD pin can be a front plane or backplane pin or GPIO function

- **Internal charge pump provides voltage required to power LCD glass**
  - Internally regulated voltage for constant contrast across MCU VDD
  - Trim register for software contrast control
  - Drive for 3V LCD glass

**Async operation** = Fully functional with alternate clock source, provided the selected clock source remains enabled

<table>
<thead>
<tr>
<th>VLPW</th>
<th>Stop</th>
<th>VLPS</th>
<th>VLLSx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>FF</td>
<td>Async operation</td>
<td>Async operation</td>
</tr>
</tbody>
</table>

¹) **OFF in VLLS0**
### Typical Power Modes in an Embedded System

#### Leading Dynamic Power
- **Run (AMO)**
  - ARM Cortex M0+ core
- **VLPR (AMO)**
  - Innovative low-power process technology (C90TFS)
- **Wait (AMO)**
  - Low-power focused platform design
- **VLPW (AMO)**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Recovery Time</th>
<th>Target Typical Idd Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run</td>
<td>-</td>
<td>$\geq 6.17\text{mA} @50\text{MHz}$</td>
</tr>
<tr>
<td>VLPR</td>
<td>-</td>
<td>$\geq 248\text{uA} @ 2\text{MHz}$</td>
</tr>
<tr>
<td>Wait</td>
<td>-</td>
<td>$\geq 3.81\text{mA} @50\text{MHz}$</td>
</tr>
<tr>
<td>VLPW</td>
<td>4us</td>
<td>$\geq 162\text{uA} @ 2\text{MHz}$</td>
</tr>
</tbody>
</table>

#### Freescale Adds Low Leakage Wake-up Unit
- Enables complete shut-down of core logic, including WIC, further reducing leakage currents in all low power modes
- Supports 16 external input pins and 5 internal modules as wakeup sources, *extend the low power wakeup capability of internal modules to even lower power modes.*
- Wakeup inputs are activated in VLLSx modes
- RTC operational on battery
- VDD/VDDA are not powered

<table>
<thead>
<tr>
<th>Mode</th>
<th>Recovery Time</th>
<th>Target Typical Idd Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLLS0</td>
<td>239us</td>
<td>357 nA</td>
</tr>
<tr>
<td>VLLS1</td>
<td>239us</td>
<td>891 nA</td>
</tr>
<tr>
<td>VLLS2</td>
<td>144us</td>
<td>1.24 uA</td>
</tr>
<tr>
<td>VLLS3</td>
<td>143us</td>
<td>1.98 uA</td>
</tr>
<tr>
<td>Standby</td>
<td>Reset</td>
<td>$&lt; 1 \text{uA}$</td>
</tr>
</tbody>
</table>
### Package Options & Device Features

<table>
<thead>
<tr>
<th>Configuration/Module</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 LQFP</td>
</tr>
<tr>
<td></td>
<td>(14 x 14 mm²)</td>
</tr>
<tr>
<td>Core, Platform and Debug</td>
<td>4 ch</td>
</tr>
<tr>
<td>DMA</td>
<td></td>
</tr>
<tr>
<td>MPU</td>
<td>yes</td>
</tr>
<tr>
<td>Peripheral XBAR (I/O supported)</td>
<td>yes</td>
</tr>
<tr>
<td>Single Wire Debug (SWD)</td>
<td>yes</td>
</tr>
<tr>
<td>System Security and Integrity</td>
<td></td>
</tr>
<tr>
<td>Cyclic redundancy check (CRC)</td>
<td>yes</td>
</tr>
<tr>
<td>RNGA (Random Number Generator)</td>
<td>yes</td>
</tr>
<tr>
<td>Watchdog timer</td>
<td>yes</td>
</tr>
<tr>
<td>External Watchdog Monitor</td>
<td>yes</td>
</tr>
<tr>
<td>Passive (Active) Tamper Pins</td>
<td>3 (one pair)</td>
</tr>
<tr>
<td>Embedded Memory</td>
<td></td>
</tr>
<tr>
<td>Flash memory (KB)</td>
<td>128/64</td>
</tr>
<tr>
<td>RAM (KB)</td>
<td>16</td>
</tr>
<tr>
<td>Embedded Memory</td>
<td></td>
</tr>
<tr>
<td>Clock Generator</td>
<td></td>
</tr>
<tr>
<td>MCG</td>
<td>FLL, Internal OSC (32 kHz or 4/2 MHz), PLL</td>
</tr>
<tr>
<td>Real Time Clock (32 kHz OSC)</td>
<td>yes</td>
</tr>
<tr>
<td>Timer/PWM</td>
<td></td>
</tr>
<tr>
<td>QuadTimer</td>
<td>4 ch</td>
</tr>
<tr>
<td>Low power timer (LPTMR)</td>
<td>1</td>
</tr>
<tr>
<td>Periodic Interrupt Timer(PIT)</td>
<td>2</td>
</tr>
<tr>
<td>Communication Interfaces</td>
<td></td>
</tr>
<tr>
<td>UART</td>
<td>4</td>
</tr>
<tr>
<td>SPI</td>
<td>2</td>
</tr>
<tr>
<td>I²C</td>
<td>2</td>
</tr>
<tr>
<td>Analog</td>
<td></td>
</tr>
<tr>
<td>24-bit Analog Front End (PGA)</td>
<td>4 (2)</td>
</tr>
<tr>
<td>16-bit SAR ADC</td>
<td>12 ch</td>
</tr>
<tr>
<td>1.2V VREF</td>
<td>yes</td>
</tr>
<tr>
<td>CMP (Number of Channels)</td>
<td>2 (12)</td>
</tr>
<tr>
<td>Human Machine Interface</td>
<td></td>
</tr>
<tr>
<td>Segmented LCD</td>
<td>4x40 (8x36)</td>
</tr>
<tr>
<td>Total GPIO pins</td>
<td>68</td>
</tr>
</tbody>
</table>

### Package Options

- **100 LQFP**  
  - 14 x 14 mm²

- **64 LQFP**  
  - 10 x 10 mm²

- **44 LGA**  
  - 5 x 5 mm²
# Kinetis M Series MCU Advantages for Electricity Metering

<table>
<thead>
<tr>
<th>Needs</th>
<th>Kinetis M Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computation</strong></td>
<td>Lowest power Cortex-M0+ core (32x32 multiply in 1 cycle) up to 48MHz.</td>
</tr>
<tr>
<td><strong>Low Power</strong></td>
<td>Less than 124.4uA/MHz VLPR Current&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Down to 357nA @VLLS0 (POR disabled)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Low Power Boot with less then 2.33mA peak current&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>User Interface</strong></td>
<td>Up to 4x40 (8x36) segment LCD driver operating in all low power modes.</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Up to 4 UARTS, 2 SPIs and 2 IIC.</td>
</tr>
<tr>
<td><strong>Memory Scalability</strong></td>
<td>From 64 KB to 128 KB of Flash. 16 KB of RAM</td>
</tr>
<tr>
<td><strong>Time Keeping</strong></td>
<td>Auto compensated RTC with high speed calibration, 5 ppm accuracy, 0.88 ppm resolution of the 1Hz pulse output and operating in all low power modes.</td>
</tr>
<tr>
<td><strong>Analog Modules</strong></td>
<td>Highest linearity and resolution AFE with 4x24bit SD with 92 dB SNR</td>
</tr>
<tr>
<td></td>
<td>Low VREF gain drift over temperature of 33ppm/°C</td>
</tr>
<tr>
<td></td>
<td>Combined gain temperature drift of the PGA, SD ADC and Internal 1.2 VREF blocks (150ppm/°C)</td>
</tr>
<tr>
<td></td>
<td>High Speed 16-bit SAR ADC and CMP.</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Passive and active tamper pins.</td>
</tr>
<tr>
<td></td>
<td>HW support for legally relevant software separation.</td>
</tr>
<tr>
<td></td>
<td>Random Number Generator (NIST: SP800-90)</td>
</tr>
<tr>
<td><strong>Robustness</strong></td>
<td>I/O pads withstanding 4 kV ESD and 6 kV PESD</td>
</tr>
</tbody>
</table>

<sup>1</sup>Typ. 248.8uA @ 2 MHz core, system, bus clock, and 1 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled.

<sup>2</sup>If independent RTC including 32 kHz oscillator operates then device consumes additional 1.3uA from VBAT terminal.

<sup>3</sup>Measured for 1.7ms linear supply voltage ramp with 3.26 V steady-state value; main function executed in 4.1 ms from applying supply voltage.
Agenda

- Introduction to electricity metering
- Kinetis M series MCUs
- Electricity metering algorithms
  - Electricity meter reference designs
  - Kinetis M development tools
  - Mastering MCU programming…
- References
Freescale Algorithms for Electricity Metering

- Electricity meter vendors require algorithms supporting calculations that adhere to either IEC/MID or ANSI C12 standards.

- Freescale offers algorithms that calculates metering quantities in either time or frequency domain

Filter-based metering algorithm
- processes signals in time domain
- leverages IIR filters
- based on elementary 32/64-bit fractional arithmetic

FFT-based metering algorithm
- processes signals in frequency domain
- leverages DFT computation
- based on elementary 32/64-bit fractional arithmetic

An algorithm must be seen to be believed. - Donald Knuth
Filter-based Metering Algorithm – Block Diagram

- Executes when power meter is supplied from the mains
- Uses high-pass and low-pass IIR filters
- Hilbert filter is used for computing reactive power and energy
- Software configuration tool is available to setup structure, filter coefficients, and generate C-header file.
- Active energy counter updated at every calculation step.

where:  
“Fs” is sampling frequency  
“D3” is decimation ratio calculated as D1-D2+1  
“N” is order of the Hilbert Transformation Filter.

For more information see AN4265
Filter-based Metering Algorithm – Hilbert Transformer

- **Magnitude and phase response**

  $$|H(e^{j\omega})|$$

  $$\arg(H(e^{j\omega}))$$

  $$H(e^{j\omega}) = \begin{cases} -j, & 0 < \omega < \pi \\ j, & -\pi > \omega > 0 \end{cases}$$

- **FIR Approximation impulse response of the ideal Hilbert Transformer**

  $$h[n] = \begin{cases} I(\beta \sqrt{(1 - [(n - n_d)/n_d]^2) 2 \sin^2(\pi (n - n_d)/2)}}/I(\beta) \pi (n - n_d), & 0 \leq n \leq N - 1 \\ 0, & \text{others} \end{cases}$$

- **Equations and practical implementation**

  for $$N=23$$, $$M=11$$ and $$\beta=0$$.

  $$y_{del}[n] = 1.0 \times x[n-11]$$

  $$y_{so}[n] = -0.0579 \times x[n]-0.0707 \times x[n-2]-0.0909 \times x[n-4]-0.1273 \times x[n-6]-0.2122 \times x[n-8]-0.6366 \times x[n-10]+0.6366 \times x[n-12]$$

  $$+0.2122 \times x[n-14]+0.1273 \times x[n-16]+0.0909 \times x[n-18]+0.0707 \times x[n-20]+0.0579 \times x[n-22]$$

- **Uses a special FIR filter for shifting a phase voltage waveform by 90°**

- **Ideal Hilbert transformer FIR approximation impulse response computed with the help of ideal Hilbert transformer impulse response and Kaiser Window coefficients.**

- **Hilbert transformer FIR approximation block design is fully automated by the software configuration tool.**
FFT Metering Algorithm – Block Diagram

- Number of samples (N) must be power-of-two (32, 64, 128, etc.)
- Ensures that processed samples represent full signal period
- Use linear interpolation technique to generate exactly power-of-two samples on a metering device with SD ADC for entire signal period.
- Sampling frequency must be at least 2x or higher than the maximum frequency included in input signal.

Where:
“N” is number of samples
“RE” is real part of the vector
“IM” is imaginary part of the vector

For more information see AN4255 and AN4847
FFT Metering Algorithm - Computation

Complex power (in Cartesian form) is defined as:

\[
\left( I_{RE}(k) - jI_{IM}(k) \right) \cdot \left( U_{RE}(k) + jU_{IM}(k) \right) = \sum_{k=1}^{N-1} \left( I_{RE}(k) \cdot U_{RE}(k) + I_{IM}(k) \cdot U_{IM}(k) + jU_{IM}(k) \cdot I_{RE}(k) - jU_{RE}(k) \cdot I_{IM}(k) \right)
\]

Where:
- \( I_{RE}(k) \) and \( U_{RE}(k) \) are real parts of \( k \)-th harmonics of input current/voltage
- \( I_{IM}(k) \) and \( U_{IM}(k) \) are imaginary parts of \( k \)-th harmonics of input current/voltage

Real part of complex power: Active power

Imaginary part of complex power: Reactive power

Root Mean Square computing (in Cartesian form) is defined as:

\[
I_{RMS} = \sqrt{\sum_{k=1}^{N-1} \left( I_{RE}(k) + I_{IM}(k) \right)^2}
\]

\[
U_{RMS} = \sqrt{\sum_{k=1}^{N-1} \left( U_{RE}(k) + U_{IM}(k) \right)^2}
\]
Agenda

- Introduction to electricity metering
- Kinetis M series MCUs
- Electricity metering algorithms
- Electricity meter reference designs
  - Kinetis M development tools
  - Mastering MCU programming…
- References
1-Phase Power Meter Reference Design with Shunt Resistor

Features

- **5 to 120A** current range (nominal current is 5A; peak current is 154A). 85 to 264V, 50/60 Hz voltage range
- **Accuracy class**: B or C (active energy EN50470-3) and 3% or 2% (reactive energy EN62053-23)
- Line frequency measurement (for precision zero-cross detection)
- Cost-effective **shunt-resistor** sensing circuit implementation
- Low-power modes including the use of **built-in RTC** (Li-battery back-up)
- **4x22 segment LCD**, including charge pump (values shown on LCD: V, A, W, Var, VA, kWh, kVarh, cos φ, Hz, time, date)
- An upper and lower tamper meter cover monitoring with time stamp
- **IEC1107 infrared hardware interface & Isolated (4kV) RS232** port for monitoring & SW upgrade
- **LED pulse** outputs (kWh, kVarh)
- **EMC proven** design (EN61000-4-2, EN610004-4)
- RF connector supporting SubGHz or 2.4 GHz 802.15.4 communications
- Xtrinsic 3-axis low power tilt sensor for electronics tamper detection (optional)

Software provided

- Application framework, Filter-based metering algorithms
Phase Power Meter RD

– Performance

• Complies with active energy EN50470 Class C: 0.15-5(120)A

• MCU clocked by 12.288MHz

• Uses 140μΩ shunt resistor

![Image]( Courtesy of Zhongshan Weiqi Electronic)

<table>
<thead>
<tr>
<th>PGA</th>
<th>SD Modulator Mode/Clock Rate</th>
<th>OSR</th>
<th>Measurement Bandwidth (kHz)</th>
<th>MCU Power Consumption (mA)</th>
<th>Performance (PF=1)</th>
<th>Performance (All PF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x16</td>
<td>Normal / 6.144 MHz</td>
<td>1024</td>
<td>3.0</td>
<td>10.88</td>
<td>+/-0.2% @ 0.075→120A (1600:1)</td>
<td>+/-0.2% @ 0.25→120A (480:1)</td>
</tr>
</tbody>
</table>
2-Phase Power Meter Reference Design with CTs

Features

- Current Class: **CL200** (TA=30A, Max. Current 200A, Starting Current 50mA)
- Nominal Voltage: 120VAC ± 20%, Nominal Frequency: 60Hz ± 10%
- Accuracy class: **ANSI C12.20, Class 0.2**
- Default Watt-hour (VAR-hour) constant: $K_h=0.2$ (range from 0.001 to 10)
- Line frequency measurement (for precision zero-cross detection)
- Current Sensor: Current Transformer (CTR 2000:1), type CHEM 9912192
- Low-power modes including the use of built-in RTC (Li-battery back-up)
- 8x20 segment LCD including charge pump and one user LED
- LED pulse outputs (kWh, kVARh) and optically isolated pulse output (via an optocoupler)
- Electronic tamper detection via a magnetometer MAG3110 and an accelerometer MMA8491Q
- ANSI C12.18-2006 Infrared Interface, optically isolated RS232 serial interface (optional only)
- RF communication supporting 2.4 GHz IEEE 802.15.4 or 900MHz RF Mesh IEEE 802.15.4g/e + WPAN/IPv6 connectivity
- Enclosure according to ANSI C12.10-2004, Form 12S (or Form2S)

Software provided

- Application framework, FFT-based metering algorithms

100 LQFP
14 x 14 mm²
2-Phase Power Meter RD – Performance

- Complies with active energy ANSI C12.20 Class 0.2% (30)200A
- MCU clocked by 48MHz
- Uses current transformers

<table>
<thead>
<tr>
<th>PGA</th>
<th>SD Modulator Mode/Clock Rate</th>
<th>OSR</th>
<th>Measurement Bandwidth (kHz)</th>
<th>MCU Power Consumption (mA)</th>
<th>Performance (PF=1)</th>
<th>Performance (All PF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>off</td>
<td>Normal / 6.144 MHz</td>
<td>102</td>
<td>3.0</td>
<td>16.3</td>
<td>+/-0.2% @ 0.090→200A (2222:1)</td>
<td></td>
</tr>
</tbody>
</table>
3-Phase Power Meter Reference Design with CTs

Features

• 5(100)A current range, nominal current is 5A, peak current is 100 A
• Tested with range 0 – 240A (320A)
• Four quadrant measurement
• 85V…264V, 50/60Hz voltage range
• Active and Reactive energy accuracy IEC50470-3 Class C, 0.2%
• Line frequency measurement (for precision zero-cross detection)
• Current transformers sensing circuit implementation
• Cost-effective bill of materials (BOM)
• Low-power modes effectively implemented, including the use of the built-in RTC
• LCD display, 4x44 segments including charge pump
• Values shown on the LCD: V,A,W,Var,VA, kWh, kVarh, Hz
• Magnetic field electronic Tamper detection via ELECTRONIC TAMPER MAG3110 sensor and tamper buttons
• Built-in user push-button
• LEDs pulse outputs (kWh, kVARh)
• IEC1107 infrared hardware interface or Optically isolated RS232 interface
• Communication interface connector, could be use for (I2C Daughter Card) for connection to a ZigBee® network

Software provided

• Application framework, Filter-based metering algorithms

100 LQFP
14 x 14 mm²
**3-Phase Power Meter RD**

- **Performance**
  - Complies with active energy EN50470 Class C: 0.15-5(120)A
  - MCU clocked by 48MHz
  - Uses current transformers

<table>
<thead>
<tr>
<th>PGA</th>
<th>SD Modulator Mode/Clock Rate</th>
<th>OS R</th>
<th>Measurement Bandwidth (kHz)</th>
<th>MCU Power Consumption (mA)</th>
<th>Performance (PF=1)</th>
<th>Performance (All PF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>off</td>
<td>Normal / 6.144 MHz</td>
<td>102 4</td>
<td>3.0</td>
<td>18.00</td>
<td>+/-0.1% @ 0.100→120A (1200:1)</td>
<td>+/-0.1% @ 0.25→120A (480:1)</td>
</tr>
</tbody>
</table>
3-Phase Power Meter Solution Based On Kinetis KM14/KL36 MCUs

Features
• 5 to 60A current range (Ib = 5A, Imax = 60A)
• 135 to 600V, 50/60 Hz voltage range
• Accuracy class: active power 0.5S, reactive power 2S
• 5ppm accuracy RTC over full temp range(-40~110℃)
• Hardware line frequency measurement
• Various low-power modes applicable for metering
• 8x32 segment LCD
• tamper meter cover monitoring with time stamp
• infrared hardware interface & 2 Isolated RS485 port
• LED pulse outputs (KWH, KVAH, MFUNC)
• Isolated electrical pulse outputs (KWH, KVAH, MFUNC)
• Xtrinsic 3-axis low power tilt sensor for electronics tamper detection (optional)
• Various external memory interface (EEPROM, Flash)
• Cost effective two layer PCB board & BOM
• EMC proven design (ESD ± 15kV, EFT ± 6KV)

Software provided
• Application framework, Filter-based metering algorithms, FFT metering algorithms (optional)
3-Phase Power Meter RD – Performance

**Accuracy**

<table>
<thead>
<tr>
<th>Number</th>
<th>Asset</th>
<th>1.0</th>
<th>0.8L</th>
<th>0.5L</th>
<th>0.8C</th>
<th>0.5C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Imax</td>
<td>lb</td>
<td>0.1lb</td>
<td>0.01lb</td>
<td>Imax</td>
</tr>
<tr>
<td>1</td>
<td>Test001</td>
<td>0.000</td>
<td>0.064</td>
<td>0.038</td>
<td>0.025</td>
<td>0.050</td>
</tr>
<tr>
<td>2</td>
<td>Test002</td>
<td>-0.019</td>
<td>0.033</td>
<td>0.044</td>
<td>0.083</td>
<td>0.088</td>
</tr>
<tr>
<td>3</td>
<td>Test003</td>
<td>-0.044</td>
<td>-0.004</td>
<td>0.013</td>
<td>-0.001</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**EMC**

FSL internal and 3 party test result:
- Passed over ± 6kv level EFT
- Passed over ± 15KV Contact ESD
3-Phase Power Meter Solution

Features

- 5 to 60A current range ($I_b = 5A$, $I_{max} = 60A$)
- 90 to 288V, 50/60 Hz voltage range
- Accuracy class: active power 0.5S, reactive power 1S
- Full four-quadrant import-export metering
- Hardware line frequency measurement – on any available phase
- Various low-power modes applicable for metering
- 4x24 segment LCD
- Various tampers supported with time stamp and electrical conditions
- Optically isolated hardware interface for communication
- LED pulse outputs (kWh, kVARh/kVAh)
- External memory interface (EEPROM)
- Cost effective two layer PCB board & BOM
- Capacitive power supply
- EMC proven design (ESD ± 35kV)

Software provided

- Application framework, DFT metering algorithms for fundamental computation

100 LQFP
14 x 14 mm²
3-Phase Power Meter RD – Performance

**Accuracy**

- **Complies with IS 13779: Class 1**
- **MCU clocked by 12.288MHz**

<table>
<thead>
<tr>
<th>Load</th>
<th>Error%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Imax</td>
<td>-0.134</td>
</tr>
<tr>
<td>4lb</td>
<td>-0.029</td>
</tr>
<tr>
<td>1lb</td>
<td>-0.014</td>
</tr>
<tr>
<td>0.05lb</td>
<td>-0.004</td>
</tr>
</tbody>
</table>

**EMC**

- FSL internal and 3 party test result:
  - Passed over ± 35kV level PESD

<table>
<thead>
<tr>
<th>SD Modulator Mode/Clock Rate</th>
<th>OSR</th>
<th>Measurement Bandwidth (kHz)</th>
<th>MCU Power Consumption (mA)</th>
<th>Performance (PF=1)</th>
<th>Performance (All PF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal / 6.144 MHz</td>
<td>1024</td>
<td>3.0</td>
<td>8.4</td>
<td>+/-0.2% @ 0.100→90A (900:1)</td>
<td>+/-0.4% @ 0.100→90A (900:1)</td>
</tr>
</tbody>
</table>
Agenda

- Introduction to electricity metering
- Kinetis M series MCUs
- Electricity metering algorithms
- Electricity meter reference designs

✅ Kinetis M development tools
  - Mastering MCU programming…
  - References
TWR-KM34Z50M Board

- 3.3V operation from USB
- Large 160-segment glass LCD
- **Onboard OpenSDA debugger**
- Headers for direct GPIO and ADC access
- Anti tamper tilt (3-axis acc.) sensor MMA8491Q
- External Tamper pins
- PB switches and LEDs
- RTC Battery
- **Onboard 6-channel waveform generator for emulation AC waveforms.**
- IRDA support
- NTC temperature sensor
- Tower system compatible
- TWRPI sensor interface
# Kinetis MCUs: Broad Software Support

<table>
<thead>
<tr>
<th></th>
<th>Freescale CodeWarrior</th>
<th>Keil (MDK)</th>
<th>IAR (EWARM)</th>
<th>Atollic (TrueSTUDIO)</th>
<th>CrossWorks for ARM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinetis Basic Device Support</td>
<td>Yes (v10.5)</td>
<td>Yes (v5.1)</td>
<td>Yes (v7.10)</td>
<td>Yes (v3.3)</td>
<td>Yes (v3.0.1)</td>
</tr>
<tr>
<td>Processor Expert Support</td>
<td>Fully Integrated</td>
<td>Stand-alone Driver Suite (Eclipse) w/ MDK Eclipse Plug-in</td>
<td>Stand-alone Driver Suite / supported integration</td>
<td>Not available in current products</td>
<td>Not available in current products</td>
</tr>
<tr>
<td>Kinetis M Bare-metal Support</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>MQX Task Awareness</td>
<td>Yes (Professional Edition)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MTB Trace</td>
<td>Yes (Production Release)</td>
<td>Yes – with CMSIS-DAP and ULINK2</td>
<td>Yes – with J-jet and CMSIS-DAP</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Free Version Limitations</td>
<td>Special Edition 64KB Debug</td>
<td>Lite 32KB</td>
<td>KickStart 16KB</td>
<td>Lite 8KB</td>
<td>No</td>
</tr>
<tr>
<td>Download Size</td>
<td>~1320MB</td>
<td>~278MB</td>
<td>~689MB</td>
<td>~500MB</td>
<td>~143MB</td>
</tr>
</tbody>
</table>

**Free Version Limitations**
- Special Edition: 64KB Debug
- Lite: 32KB
- KickStart: 16KB
- Lite: 8KB
- No
Processor Expert: Overview

- Easy-to-use GUI based tool to create a set of device drivers for your application very quickly and efficiently

- Driver code created exactly as you configure it. Not a “lowest common denominator” generic driver. You can take advantage of the precise features you want

- Header and source files created automatically. Prevents errors and conflicts between the drivers and the h/w

- Generated code tailored on configuration choices. Only functions you enable are implemented in code (size optimized)

- Processor Expert now available with support for IAR, Keil and GCC tool chains

- Training on www.freescale.com and www.youtube.com

- www.processorexpert.com

“You don’t have to sit down with over 1000-page data sheet and figure out where all the registers are and how to set everything up.”
Kinetis M Series MCUs Bare-metal Drivers and Software Examples

- Supported development tools:
  - IAR EWARM 6.5x
  - CW MCU 10.x
  - CrossWorks 2.3.3
  - KEIL uVision 5.1 (Rev. 2.3)
- Bare-metal software driver available for every on-chip peripheral
- Over sixty software examples
- Complemented by tutorials:
  - Boot modes analysis
  - Bit Manipulation Engine (BME) and IOPORT benchmark
  - FreeMASTER integration
FreeMASTER Run-Time Debugging Tool

Application control and monitor

Live graphs, variable watches, and graphical control page

Interfaces with Excel and Matlab

Supports:
- HCS08, HC12, HCS12 and HCS12X BDM
- 56F8000, 56F8100 and 56F8300 JTAG
- SCI driver (FMASTERSCIDRV) for all platforms
Agenda

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• Kinetis M development tools

✔ Mastering MCU programming…

• References
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References
References

- Kinetis M Series MCUs, available on freescale.com
- Kinetis M Support for Distinct Separation of Legally Relevant Software (document KINETISMWP)
- Filter-Based Algorithm for Metering Applications (document AN4265)
- FFT-Based Algorithm for Metering Applications (document AN4255)
- Using an FFT on the Sigma-Delta ADCs (document AN4847)
- Kinetis-M One-Phase Power Meter Reference Design (document DRM143)
- Kinetis M Bare-metal Software Drivers (document KMSWDRVAPI)
- TWR-KM34Z50 Tower Module (document TWRKM34Z50M)
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2014 seminar topics include

- QorIQ product family update
- Kinetis K, L, E, V series MCU product training

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