Motor Control trends with Freescale MCU

Eduardo Viramontes – Applications Engineer
Objectives

By the end of this session, you should be able to

• Know the newest Control solutions provided by Freescale including
  ▪ MP16
  ▪ DSC portfolio
  ▪ PPC
  ▪ Kinetis

• Understand what makes the Anguilla Black an ideal device for advanced motor control.
### Motor Control and Power Conversion Market Trends

<table>
<thead>
<tr>
<th>Motor Control</th>
<th>Power Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduce power consumption</strong></td>
<td>Increase Conversion Efficiency</td>
</tr>
<tr>
<td>Intelligent motor control improves efficiency by 30 percent or more</td>
<td>Cost-effective soft switching techniques</td>
</tr>
<tr>
<td><strong>Reduce system and development cost</strong></td>
<td>High Power Density</td>
</tr>
<tr>
<td>More on-chip peripherals to reduce component count</td>
<td>Compact size: high watt per cubic inch</td>
</tr>
<tr>
<td><strong>Reuse software, hardware and tools across platforms</strong></td>
<td>High Intelligence Control</td>
</tr>
<tr>
<td>Ease software migration across wide performance range</td>
<td>Digital Controlled Power conversion</td>
</tr>
<tr>
<td><strong>Cost-effective safety, reliability and security</strong></td>
<td>Low Cost</td>
</tr>
<tr>
<td>On-chip safety and security protection</td>
<td>System monitoring and protection with less components usage</td>
</tr>
</tbody>
</table>

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## Motor Control – Freescale Alignment with Trends

<table>
<thead>
<tr>
<th>Market Trend</th>
<th>Freescale Alignment with Customer Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduce power consumption</strong></td>
<td>• Vector and sensorless control technology designed into every motor control processor</td>
</tr>
</tbody>
</table>
| **Reduce system and development cost**| • 8- and 16-bit MCUs start at <$0.70  
   • 16-bit DSCs for ACIM and PMSM solutions  
   • 32-bit Power Architecture® MCUs for standard/premium drives |
| **Reuse software, hardware and tools across platforms** | • Rich tools, training, reference designs and libraries  
   • Devices are ruggedized with long life and reliability  
   • Industrial products ship 10+ years, with high quality and expert customer support |
| **Cost-effective safety, reliability and security** | • Secure SRAM, on-chip data fusing to protect against IP cloning  
   • Hardware encryption to protect against network data hacking  
   • Watchdog and ECC protection against soft errors  
   • Certified IEC software modules |
Motor Control Target Applications

► Pumps and fans
   • pool pumps, factory systems

► HVAC
   • heating fans, air-conditioners

► Industrial drives
   • Manufacturing assembly, robotics, wind turbines, printing presses

► Appliances
   • washers, dryers, power tools

► Medical
   • scanners, pumps, diagnostic and therapy

► Automotive Motor Control Trends
   • Fuel/Water pumps, HVAC Fan Control, Window lift
   • Increasing adoption of electric and hybrid vehicles continues to drive BLDC demand
Industrial Motor Control Solutions

Freescale Motor Control Processors
Typical Motor Control MCU Peripheral Functions

► Timer:
  • PWM signals < 20Khz
  • Dead time insertion
  • Commutation (mask-out)
  • ADC triggering
  • Fault control

► ADC
  • Measure current

► Delay block
  • Set ADC measurement at specific times

► Position decoder
  • Quadrature decoder inputs if not sensorless
Many Different Motor Types …

- **DC Motor**
- **Brushless DC Motor (BLDC)**
- **Stepper Motor (half step)**
- **Stepper Motor (full step)**
- **AC Induction Motor (ACIM)**
- **Permanent Magnet Synchronous Motor (PMSM)**
- **Switched Reluctance Motor**
MC9S08MP16

Enabling Safe, Accurate and Inexpensive BLDC Motor Control

http://www.freescale.com/S08MP16
Core / Temp / Package
- Industrial Version: 50MHz (25MHz bus), -40to105C
- Automotive Version: 40MHz (20MHz bus), -40to125C
- 2.7V to 5.5V operating range

Memory
- 16KB Flash / 1KB RAM
- 12KB Flash / 512B RAM

Features
- 2x FlexTimers (6ch + 2ch) – automatic fault protection
- 3 Analog Comparators – h/w sample trigger from PWM module allowing comparison at any point in cycle
- 2x Programmable Delay Blocks (PDB)
- 12-ch 12-bit ADC – 3.5 uS conversion, h/w trigger from PWM module allowing conversion at any point in cycle
- Programmable Gain Amplifier (PGA)
- 8-bit Modulo Timer Module (MTIM)
- LIN SCI, SPI, IIC
- 3x 5-bit DAC used as a 32 tap voltage reference
- RTC
- Software Programmable Internal Clock Source
- 3x low power modes & peripheral CLK gating
- Power Management Controller (PMC)
- KBI
- POR / LVI – supports 4 interrupt priority levels
- Background Debug Mode Interface/ICE

System Protection
- Cyclic Redundancy Check Generator (CRC)
- Watchdog Timer with Independent Clock Source
Freescale Digital Signal Controller- 56800E family
What is Digital Signal Controller

• Specialized microprocessor whose architecture contains a core engine capable of competitively performing both microcontroller and digital signal processor functionalities
• Core processing capability applicable to many types of system solutions
• Common basic features:
  > MAC, single instruction cycle allowing several memory accesses, address generation units, algorithms for efficient looping
• Specialized Low cost, high performance on-board interfaces utilized in implementing embedded control applications:
  > PWM; multifunction timer; high speed ADCs; DACs; Comparators; SCIs (UART); SPIs; CANs and I2Cs, etc.
• Embedded nonvolatile memory:
  > Flash memory, ROM or EEPROM
• Easy to use development tools
56800/E Family Combining Signal Processing and Controller Functionality

Traditional Microcontroller
- Designed for Controller Code
- Compact Code Size
- Easy to Program
- Inefficient Signal Processing

Traditional DSP Engine
- Designed for DSP Processing
- Designed for Matrix Operations
- Complex Programming
- Less Suitable for Control

- Instructions Optimized for Controller Code, DSP, Matrix Operations
- Compact Assembly and “C” Compiled Code Size
- Easy to Program
- Additional MIPS Headroom and extended addressing space
### DSC Roadmap

#### Flash Size

<table>
<thead>
<tr>
<th>Size</th>
<th>Low Power</th>
<th>Large Capacity</th>
<th>High Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16kB</td>
<td>2009</td>
<td>32kK</td>
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<tr>
<td>&lt;32kB</td>
<td>MC56F812x</td>
<td>MC56F832x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40MHz</td>
<td>60MHz</td>
<td></td>
</tr>
<tr>
<td>&lt;64kB</td>
<td>MC56F802x</td>
<td>MC56F833x</td>
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<tr>
<td></td>
<td>32MHz, HR PWM, ADC</td>
<td>60MHz</td>
<td></td>
</tr>
<tr>
<td>&lt;144kB</td>
<td>MC56F814x</td>
<td>MC56F835x</td>
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<tr>
<td></td>
<td>40MHz</td>
<td>60MHz</td>
<td></td>
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<tr>
<td>&lt;280kB</td>
<td>MC56F815x</td>
<td>MC56F836x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40MHz</td>
<td>60MHz</td>
<td></td>
</tr>
<tr>
<td>&lt;560kB</td>
<td>MC56F816x</td>
<td>MC56F837x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40MHz</td>
<td>60MHz</td>
<td></td>
</tr>
</tbody>
</table>

#### Performance

- **MC56F832x**: 32 Bit Core, 100MHz, DMA, FAST ADC & PWM
- **MC56F833x**: 32 Bit Core, 100MHz, DMA, FAST ADC & PWM
- **MC56F834x**: 32 Bit Core, 100MHz, DMA, FAST ADC & PWM

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- Production - Available NOW
- Execution - Specification Frozen, in design
- Proposal - Specification Subject to Change
Freescale Digital Signal Controller- 56800E family
Ultra Low cost 56F8000 member: 56F8002, 56F8006

- 32 MHz/32 MIPS 56800E Core
- 1.8-3.6V Operation
- 12K - 16K Bytes Program FLASH with Flash security
- 2K Bytes Program/Data RAM
- Tunable Internal Relaxation Oscillator and 32KHz clock
- Phase Locked Loop (PLL)
- Up to 96 MHz Peripherals – Timers, PWM & Hi-SCI
- 6 Output PWM Module with 4 Programmable Fault Inputs
  - Programmable Dead timer insertion
  - Programmable PWM generation for Power supply apps
  - Multiple PWM Frequency outputs
- Two Programmable Gain Amplifiers with x2, x4, x8, x16 gains (Clocked in order to cancel input offset)
- Two 12-bit ADCs with up to 24 Inputs, 2.5us Per conversion
- Programmable Delay Block provides precise control of ADC/PGA sample times relative to PWM reload cycles
- Three High Speed Analog Comparators
- 2 multiple function Programmable Timers
- Computer Operating Properly Timer
- One Periodic Interval Timer (PIT)
- 1 High Speed Serial Communication Interface (Hi-SCI)
- 1 Serial Peripheral Interface (SPI)
- I²C Communications Interface
- Up to 40 GPIOs – Versatile pin usage
- JTAG/EOnCE™ Debug Port
- Lead Free “Green” Packages
- Industrial temp: -40C – 105C

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Anguilla Black
56F824x / 56F825x Features

- 60 MHz/60MIPS From 56800E Core
- Up to 60 MHz Peripherals
  - 8 Output PWM Module
    - 520ps PWM duty cycle resolution
  - 2 x12-bit ADCs with total of 16 Inputs
  - 500ns conversion rate
  - Built-in PGA - 1x, 2x, 4x, gains
- 1 x 12-bit Digital to Analog Converter
- 3 x 5bit Digital to Analog Converters
- 3 Analog Comparators
- 8 x16-bit Enhanced Multifunction Programmable QTImers
- Cyclic Redundancy Check Generator (CRC)
- 5v tolerant up to 54 GPIOs
- Inter Module Cross-Bar
Motor Control Use Case

**K10 Family**

- **ARM Cortex M4 Core**
- **System**
- **Internals & external watchdogs**
- **Memory protection**
- **FlexMemory**
- **Serial programming interface**
- **External bus**
- **Low/high frequency oscillators**

- **Memories**
- **Program flash**
- **RAM**
- **Cache**

- **Clocks**
- **Phase-locked loop**

**FlexMemory:**
- Saving motor calibration data
- Remote update bootloader

**DSP hardware:**
- Accelerates motor control calculations

**DMA:**
- Off-loads CPU from repetitive data transfers

**16-bit ADC & PGA:**
- Measures 3 phase bridge current and voltage

**Analog Comparator:**
- Detects back EMF
- Monitors over current

**Programmable delay block:**
- Schedules delayed ADC conversions relative to Timer triggers

**Timers:**
- Drives various motor types including stepper, BLDC, and PMAC motors with sensor or sensorless algorithms
- Built-in quadrature decoder detects motor speed

**I²C, UART, SPI, CAN:**
- Communicates with HMI processor

**Communication**
- **I²C x2**
- **PS x2**
- **UART x6**
- **SPI x3**
- **CAN x2**

**HMI**
- **Capacitive touch sense**

**Debug Interfaces**

**Interruption controller**

**Floating-point unit**

**DMA**

**Low voltage monitor**

**NAND flash controller**

**Phase-locked loop**

**I²C, UART, SPI, CAN:**
- Communications with HMI processor
Power Architecture for Motor Control: MPC5604P
MPC5604P

Power Architecture® Core
- Up to 64 MHz e200 zenoh core, 32-bit Power Architecture Book E CPU with Harvard architecture
- VLE instruction set encoding for code size footprint reduction

On-Chip Memory Options

<table>
<thead>
<tr>
<th>Device</th>
<th>MPC5602P</th>
<th>MPC5603P</th>
<th>MPC5604P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Flash with ECC</td>
<td>256K</td>
<td>384K</td>
<td>512K</td>
</tr>
<tr>
<td>DataFlash® with ECC</td>
<td>64K</td>
<td>64K</td>
<td>64K</td>
</tr>
<tr>
<td>SRAM with ECC</td>
<td>24K</td>
<td>32K</td>
<td>40K</td>
</tr>
<tr>
<td>FlexRay</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Interrupt Controller</td>
<td>100ch</td>
<td>100ch</td>
<td>144ch</td>
</tr>
</tbody>
</table>

I/O Peripherals
- 1 x high speed FlexCAN with 32 Message Buffers (MB)
- 1 x Safety port (can be used as additional FlexCAN – 32 MB)
- 1 x FlexRay Controller - Dual Channel with 32 MB
- 2 x LinFlex
- 4 x DSPI (4 independent chip selects each)
- 1 x FlexPWM (4 channels with 4 fault inputs)
- 2 x eTimer (6 channels incl. quad decode)
- 2 x ADC - 2 x 12 ch.(4 shared channels)
  - 10-bit, conversion time 700 nsec (2 x 6 ch., 4 shared on 100-pin package)
- 1 x CTU triggering unit: 32 input channels, 8 events, 24 ADC cmds.
- 1 x Fault collection unit

System
- 2 x PLL (one FM-PLL, one for FlexRay™)
- Crossbar switch architecture for concurrent access to peripherals
- 16-ch. eDMA
- 16 MHz internal RC OSC
- Junction temperature sensor
- Non-Maskable Interrupt
- Programable Watchdog

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Electric Motor Control Peripherals

**Cross Triggering Unit**
- Allows mcTIM, PWM, ATD to be synchronized
- Automatic ADC & eTimer acquisitions
- No CPU intervention during the control cycle

**FlexPWM**
- Based on DSC PWM
- Optimized for 3ph motor control
- One „extra“ pair of PWM integrated
- Includes dead time insertion, fault channels, center/edge alignment, Distortion correction, …
- Register protections
- Double buffered registers
- eDMA supported
- 2 x BUS frequency → high resolution

**Timer Module:**
- DSC based
- Six Ch IC/OC
- Double buffered registers for detecting two edges in a row
- eDMA supported
- Integrated quad decoder support
- 2 x BUS frequency → high resolution

**2x ADC**
- Up to 24 independent and 4 shared channels
- 10-bit
- 700 nsec conversion time
- Limit checking & zero crossing detect
Motor Control PWM Peripheral Module

Main Features

- 4 Sub-modules, each with complementary PWM generation, Isense IC/OC and fault input
- 16 bits of resolution for center, edge aligned, and asymmetrical PWMs
- PWM outputs can operate as complimentary pairs or independent channels
- Independent control of both edges of each PWM output
- Independently programmable PWM output polarity
- Separate dead time for rising and falling edges
- Each complementary pair can operate with its own PWM frequency and deadtime values
- All outputs can be programmed to change simultaneously via a "Force Out" event

Safety Features

- Write protection for critical registers
- Fault inputs can be assigned to control multiple PWM outputs
- Programmable filters for fault inputs

Internal triggers

- Permanent magnet synchronous motor (PMSM, PMAC)
- Brushless DC motor (BLDC)
- Brush DC motor (BDC)
- AC induction motor (ACIM)
- Switched reluctance motor (SRM)
- Variable reluctance motor (VRM)
- Stepper motors
- DC/DC converters

PWM Modes

- Complementary Pairs
- Independent Channel

Faults

- Internal triggers
- Independent Edge Control
Summary

► Cutting Edge. Cost Effective. Complete. Freescale offers technology for every motor control application

► Energy efficient motor control
   Vector and sensorless control technology in motor control processors
   8- and 16-bit
   16-bit DSCs for ACIM and PMSM solutions
   32-bit Power Architecture® MCUs for standard and premium drives

► Strong technical support
   Rich tools, training, reference designs, libraries
   Devices are ruggedized with long life and reliability
   Industrial products ship 10+ years with high quality and expert support

► Cost-effective safety and security on-chip
   Protect against IP cloning, network data hacking and soft errors
Freescale:

- Motor Control Homepage – [www.freescale.com/motorcontrol](http://www.freescale.com/motorcontrol)
- 8-bit Microcontrollers – [www.freescale.com/8bit](http://www.freescale.com/8bit)
- 16-bit DSC – [www.freescale.com/dsc](http://www.freescale.com/dsc)
- Industrial Segment – [www.freescale.com/industrial](http://www.freescale.com/industrial)
Sensorless PMSM Motor Control Using MC56F80xx

- MC56F80xx digital signal controller
- 3-phase AC/BLDC High Voltage Power Stage Board
- 1-phase line input 110/230VAC @ 50/60Hz
- Appliance PM motor
- Initial rotor position detection
- Full torque at motor start-up
- Field weakening
- Application based on C-callable library functions (GFLIB, GDFLIB, MCLIB, ACLIB)
- Current control loop execution time: 55us
- Speed control loop with Field weakening execution time: 17us
- Flash: ~ 6KB, RAM ~ 1.5KB
Low Cost BLDC Motor Control Demo Board

- Brushless motor, Maxon EC-200187, 6W 9V
- Motor interface connector
- Input power connector
- Daughter card connector for connecting the 56F8013 demonstration board
- LED power indicator
- Motor bus voltage sense logic
- Motor bus current sense logic
- Back EMF phase voltage sense logic
- Zero-crossing logic
- Hall-effect/zero-crossing selector
- 3-phase H-bridge power stage
- Power regulation logic
- (Optional) Five on-board real-time user debugging LEDs

Order Number: APMOTOR56F8000
BLDC Control Using MC56F8013

► Three-phase brushless DC motor sensorless drive
► Designed to fit into fan, pump and compressor applications
► Using MC56F8013 32 MIPS hybrid controller
► Available for two power stages and two motors
► Input power supply voltage +12 Vdc for power stages
► Control technique incorporates:
  • Sensorless, trapezoidal control of 3-phase brushless DC motor with back-EMF sensing
  • Using A / D converter zero-cross sensing for sensorless control
  • Speed and current closed loop with PI controller
► Speed range: 200 – 2000 and 500 – 5000 RPM (depending on the motor used)
► Manual interface (run/stop switch, up/down pushbuttons)

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High Speed Application

- 3-Phase BLDC Drive Using Variable DC Link Six-Step Inverter
- Application Note Number: DRM078
- Speed can exceed 10Krpm
MC9S08MP16: Enablement

- DEMO9S08MP16 (generic demo board)
- Demos
  - Sensorless BLDC Motor Control using ADC approximation
- Reference Designs
  - Sensorless BLDC Motor control using Comparators
  - 3-Ph ACIM V/Hz Drive with PFC
  - Industrial HID Lamp with PFC
- Software Libraries
  - S08 Math and Embedded
- Application Notes
  - S08MP16 comparators for BLDC sensorless motor control
  - Using MP16 peripheral modules (FTM, Delay block, ADC)
  - high speed BLDC sensorless control using ADC approximation
  - BLDC Motor Control using Hall Sensors
  - Using FlexTimer in DC/BLDC Motor Control Application
Introducing the MC56F82xx DSC Family

The new MC56F82xx Digital Signal Controller (DSC) delivers an affordable solution for a smoother, better power supply and motor control.

High Speed PWM module – 520ps duty cycle resolution

- Up to 9 Enhanced Flex Pulse-Width Modulator (eFlexPWM) channels, including 6 with NanoEdge placement, allow for center, edge-aligned and asymmetrical PWM as well as double-buffered registers with integral reload rates, and half-cycle reload capability for precise switching frequency generation.

High speed ADC with Programmable Gain Amplifiers

- PGA-enabled ultra-fast Analog-to-Digital Converters (ADCs) that can achieve up to 3.33 million samples per second to help reduce signal ripple to precisely modulate energy. A maximum ADC clock frequency of 10 MHz allows a single conversion time of 8.5 ADC clock cycles (850ns) and additional conversions at 6 ADC clock cycles (600ns)

Inter-module Cross Bar

- The Inter-Module Crossbar Switch (XBAR) allows programmable internal module connections between and among eFlexPWM, ADC, QuadTimers, DACs, HSCMPs and package pins.
## MC56F82xx Advanced Features and Benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Up to 9 eFlexPWM channels, including 6 with NanoEdge placement</td>
<td>Reduce signal ripple to precisely modulate energy</td>
</tr>
<tr>
<td>• PGA-enabled ultra-fast ADCs can achieve up to 3.33 million samples per second</td>
<td></td>
</tr>
<tr>
<td>• eFlexPWM allows for center, edge-aligned and asymmetrical PWM, double-buffered registers with integral reload rates and half-cycle reload capability</td>
<td>Achieve precise switching frequency generation</td>
</tr>
<tr>
<td>• Maximum ADC clock frequency of 10 MHz allows a single conversion time of 8.5 ADC clock cycles (850ns) and additional conversions at 6 ADC clock cycles (600ns)</td>
<td>Precisely measure power supply and motor control currents</td>
</tr>
<tr>
<td>• Dual Harvard-style architecture permits up to 3 simultaneous accesses to program and data memory and 3 execution units operating in parallel</td>
<td>Allow as many as 6 operations per instruction cycle</td>
</tr>
<tr>
<td>• The MCU programming model and optimized instruction set for advanced power conversion and motor control algorithms</td>
<td>Allow for generation of efficient, compact DSP and control code</td>
</tr>
<tr>
<td>• Inter-Module Crossbar Switch (XBAR)</td>
<td>Allow programmable internal module connections between and among eFlexPWM, ADC, QuadTimers, DACs, HSCMPs and package pins</td>
</tr>
<tr>
<td>• Dynamically boost ADC input range</td>
<td>Eliminate the need to buy external amplifiers and reduce overall BOM costs</td>
</tr>
<tr>
<td>• Embedded 12-bit DAC provides a reference to on-chip comparators or generates a waveform to a package pin, generating square, triangle and sawtooth waveforms</td>
<td>Eliminate the need for external components</td>
</tr>
<tr>
<td>• Up to 64KB of embedded, secured and protected flash memory with EEPROM emulation capability.</td>
<td>Simplify system complexity and cost</td>
</tr>
</tbody>
</table>
Markets and Applications

Advanced Power Conversion

- AC/DC, DC/AC, DC/DC and AC/AC Conversion
- Board Switched-Mode Power Supply
- Battery Management
- Solar Inverter

Advanced Motor Control

- ACIM, BLDC, PMSM, SR and Stepper
- Field-Oriented Control
- Industrial Control
- Large Home Appliances

Energy

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MC56F82xx Enablement

- CodeWarrior for DSC
  - Processor Expert support

- TWR-56F8257 Board
  - The board can be used as a standalone development board or as part of a Tower System kit
  - Out-of-box labs

- FreeMASTER Support
  - FreeMASTER is one of the off-chip drivers, which supports communication between the target microcontroller and PC

- AppNotes
  - Microinverter Implementation
  - EEPROM Emulation

http://www.freescale.com/ MC56F82xx
Switch Mode Power Supply Reference Design

LLC resonant half-bridge converter, synchronous rectifier and buck converter are controlled by the 56F8247 DSC.
The eFlexPWM architecture is configurable, up to 4 sub-modules (shown).
In this example, both PWMs have the same duty-cycle. However, the edges are shifted relative to each other by simply biasing the compare values of one waveform relative to the other.

Alternatively, if the waveforms are generated by different sub-modules, the waveforms can be shifted by simply changing the Init value of one sub-module relative to the other.

This is useful for reconstructing phase currents from a DC bus shunt when the amplitudes of the modulated signals are near zero.
Once
- The ADC starts to sample just one time whether you use the START bit or by a sync pulse. This mode must be re-armed by writing to the ADCR1 register again if you want to go capture another scan.

Triggered
- Sampling begins with every recognized START command or sync pulse.

Loop
- The ADC continuously take samples as long as power is on and the STOP bit has not been set.

Sequential Mode
- Sequential will sample SampleN one after another. Channel ANAx are sampled by ADCA and Channel ANBx are sampled by ADCB.

Parallel Mode
- Simultaneous: Parallel can sample SampleN from Group1 and SampleN from Group 2 at the same time.
- Independent: ADCA and ADCB can operate independently. At end of scan of each ADC, they generate separate interrupt request.
<table>
<thead>
<tr>
<th>Distributor</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow Brasil</td>
<td>+55.11.3613.9300</td>
<td><a href="mailto:sac@arrowbrasil.com.br">sac@arrowbrasil.com.br</a></td>
</tr>
<tr>
<td>Avnet Electronics</td>
<td>+55.11.5079.2150</td>
<td><a href="mailto:vendas@avnet.com">vendas@avnet.com</a></td>
</tr>
<tr>
<td>Farnell Newark</td>
<td>+55.11.4066 9400</td>
<td><a href="mailto:vendas@farnell-newarkinone.com">vendas@farnell-newarkinone.com</a></td>
</tr>
<tr>
<td>Future Electronics</td>
<td>+55.19.3737.4100</td>
<td><a href="mailto:future.campinas@future.ca">future.campinas@future.ca</a></td>
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<tr>
<td>Informat</td>
<td>+55.11.3350.0200</td>
<td><a href="mailto:denis@grupoinformat.com.br">denis@grupoinformat.com.br</a></td>
</tr>
<tr>
<td>Karimex Componentes</td>
<td>+55.11.5189.1900</td>
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