Overview
One of the most useful home appliances used in households across the world is a washing machine. Washing machine features are still being improved thanks to incorporating MCUs that allow manufacturers to implement many useful features. Typical features available in the most modern consumer washers include:

- Plenty of pre-defined programs for different laundry types
- Variable temperature settings
- Variable spin speed
- Quick wash programs
- Variable load support
- Water level control
- Delayed execution

Washing Machine Varieties
There are many types of washing machines varying in mechanical construction, motor types driving a drum, a control system of the motor control part, human interface, level of energy efficiency, washing performance, drying performance and water consumption.

Mechanical Construction
1) Drum position
   a. Horizontal washers (dominate in EU markets)
   b. Vertical washers (popular in US and AP markets)
2) Drum loading
   a. Front load washers
   b. Top load washers
3) Drive construction
   a. Belt driven
   b. Direct drive

Motor Types Driving the Washer:
1) Vintage motor construction
   a. Single-phase ACI motors
   b. Single-phase universal motors
2) Modern motor construction
   a. Three-phase ACI motors
   b. Three-phase PMS motors

Control System for Motor Control
Modern control systems focus on more sophisticated control topology supporting sinusoidal control. One of the most popular control topologies is field-oriented control (FOC), allowing for maximum efficiency, maximum motor power, minimum torque ripple, reduction of audible noise and utilization of the maximum motor torque that is required at motor acceleration during the motor/drum startup. The drive solution with ACI motor requires information about rotor speed. In the case of the PMS motor drive, information about the rotor position and speed is required. The control algorithm of the PMS motor processes the rotor position and calculates the speed based on the difference of the rotor position in time. Since the position sensor is relatively expensive, the washer manufacturers focus on sensorless control techniques eliminating the position sensor. The sensorless control techniques require powerful MCUs.

Typical Horizontal Belt-Driven Washing Machines

Motor type
- Three-phase ACIM (two poles)
- Three-phase PMSM (eight poles)

Load capacity of standard washer size 60 cm x 60 cm x 85 cm
- From 5 kg up to 12 kg
- Typically—7 kg or 8 kg

Drum spin speed
- From 1000 RPM to 1600 RPM

Transmission ratio—drum to motor
- From 1:6 to 1:16
- Typically around 1:10

Motor power
- About 750 W

Motor torque
- About 2 nm
- In some cases 3.5 nm

Key features of washer applications
- Motor control part
  - FOC
Belt-Driven vs. Direct Drive Washers

The most common washing machines contain belts. This mechanical construction consists of two pulleys with the belt transmitting the power, torque and the speed from the motor to the drum. The smaller pulley is mounted on the motor shaft while the larger pulley is mounted on the drum shaft. Assuming the typical motor to drum transmission ratio is 1:10, the drum speed at spinning operation of 1600 RPM and startup motor torque 2 nm, we can simply calculate the speed of the motor corresponding to the spinning operation as 16000 RPM and torque on the drum during the startup as 20 nm.

Direct drive washing machine construction does not include pulleys and belts, therefore the motor shaft is directly mounted to the drum shaft. The motor supporting this mechanical construction is optimized for high torque and relatively low-speed operation. This type of motor, called “Pancake Motor,” has specific construction as shown in figure 1.

Typical construction of the pancake motor includes:
- Rotor construction—permanent magnet
- Stator winding—three-phase
- 24 to 48 poles

Freescale Support for Washing Machine Applications

The Freescale MCU portfolio provides solutions for a wide variety of washing machine applications. The Freescale DSC family is an ideal solution for such a complex application requiring a powerful core and smart and flexible peripherals like eFlex PWM, ADCs, timers, crossbar and hardware interconnectivity. Typical DSC-based MCUs include:
- MC56F825x/4x family
- MC56F844x/5x/7x family

The MC56F825x/4x is a member of the Freescale family of DSCs based on the 56800E core. Family key features include:
- Core operation frequency—60 MHz
- High-speed peripheral clock—120 MHz
- Flash memory—from 48 KB to 64 KB
- RAM memory—from 6 KB to 8 KB
- eFlex PWM module—Six channels
- 12-bit ADC with programmable gain—from 2 x 4 channels to 2 x 8 channels
- Analog comparator with integrated 5-bit DAC—three modules
- 12-bit DAC—one module
- Crossbar module
- Queued SCI, queued SPI, I²C, MSCAN

The MC56F844x/5x/7x is the initial family of 32-bit 56800EX core-based DSCs. The 56800EX includes all features of the 56800E core as well as the following enhancements:
- 32-bit x 32-bit MULT/MAC operations
- Address generation unit (AGU) includes shadow registers
- Bit-reverse address mode supporting FFT
- New bit manipulation instruction—BFSC

Family key features:
- Core operation frequency—up to 100 MHz
- High-speed peripheral clock—120 MHz
- Program/data flash memory—up to 256 KB
- Program/data RAM—up to 32 KB
- FlexMemory
- Up to 32 KB of FlexNVM—additional program or data flash
- Up to 2 KB of FlexRAM—additional RAM memory
- eFlex PWM module—Eight channels
- 12-bit ADC with 300 ns conversion time—2 x 8 channels
- 16-bit SAR ADC with temperature sensor—1 x 24 channels
- DMA—Four channels
- Two quad timer modules
- One quadrature decoder module
- Two periodic interval timers
- Analog comparator with integrated 6-bit DAC—four modules
- 12-bit DAC—one module
- Crossbar module
- Three queued SCIs, three queued SPIs, two I²Cs, one FlexCAN

Conclusion

The washing machine is one of the most sophisticated white goods in terms of motor control due to a wide speed range, load variation and cost optimization. Freescale provides dedicated MCUs that are capable to effectively solve the needs of these complex applications.

Comprehensive information about MCUs, programming and debugging tools and universal high voltage inverters for simplifying application development can be found at freescale.com. Here you can also find application notes and design reference manuals describing details of the specific washing machine application and providing design hints utilizing the great features of Freescale MCUs.

Reference Designs—DRM110, DRM075, DRM070, DRM099
Application Notes—AN3476, AN3234
Videos—PMSM sensorless motor drive
High voltage power stage—3PHACBLDCHVPSUG

Additional information related to the washer application, such as touch control, connectivity (ZigBee) and water level measurement (pressure sensors), can be found at freescale.com.
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