TOSHIBA

Leading Innovation

Microcontrollers

Introduction to Toshiba PMD Microcontrollers

April 2008

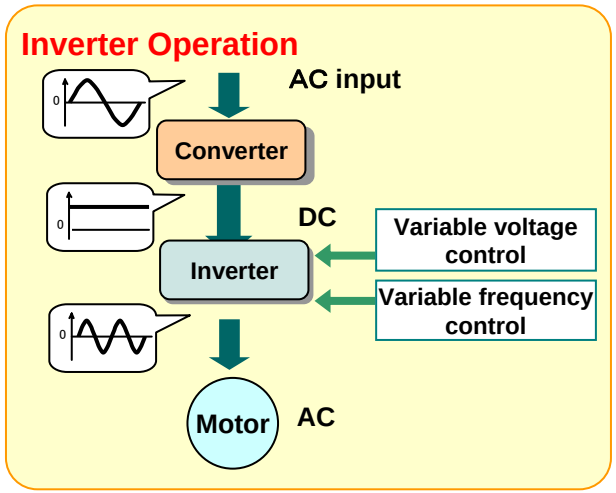
Rev.1.0

TOSHIBA CORPORATION
Semiconductor Company

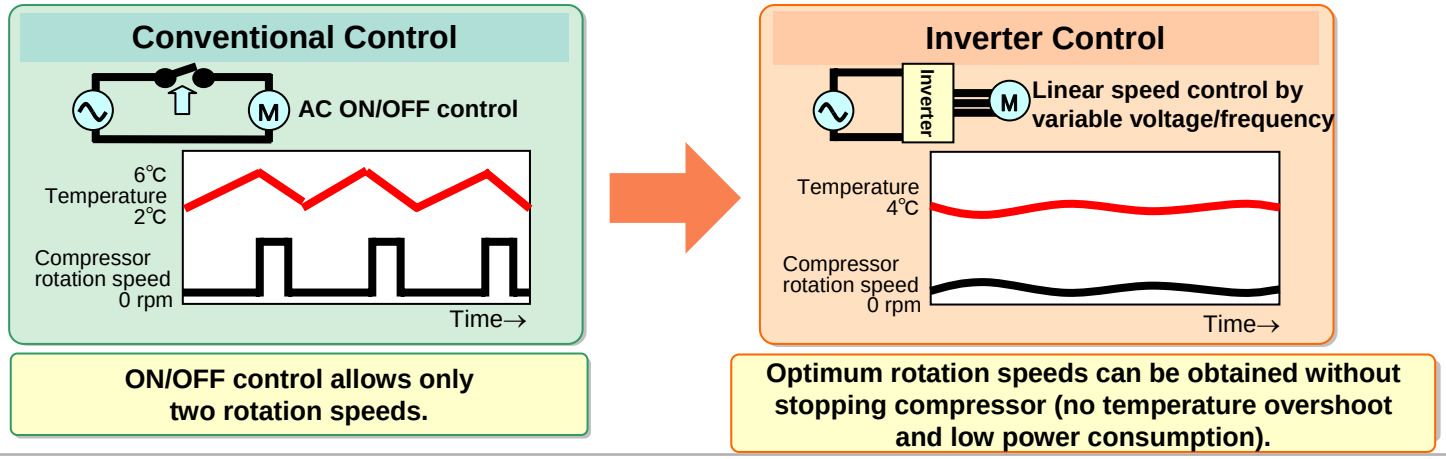
Inverter Motor Control

An inverter is a circuit for converting direct current into alternating current, enabling variable voltage/variable frequency control. They are widely used for controlling motors. Since motor speed can be adjusted flexibly according to the required workload, energy savings can be expected.

Inverter motor control applications include home appliances such as air conditioners (outdoor units), refrigerators using compressors, and washing machines.



Inverter Motor Control (Example: Refrigerator)

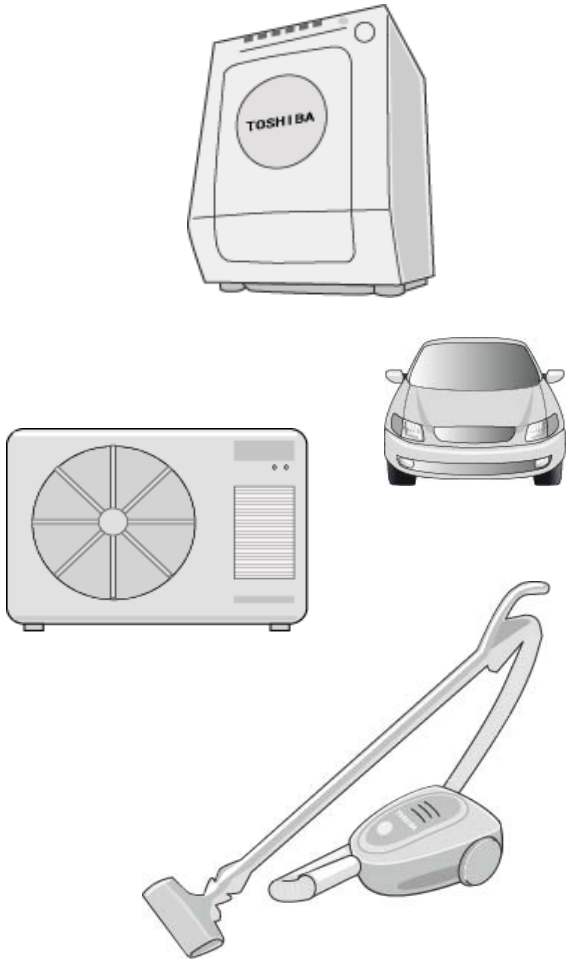


Toshiba Microcontrollers for Motor Control

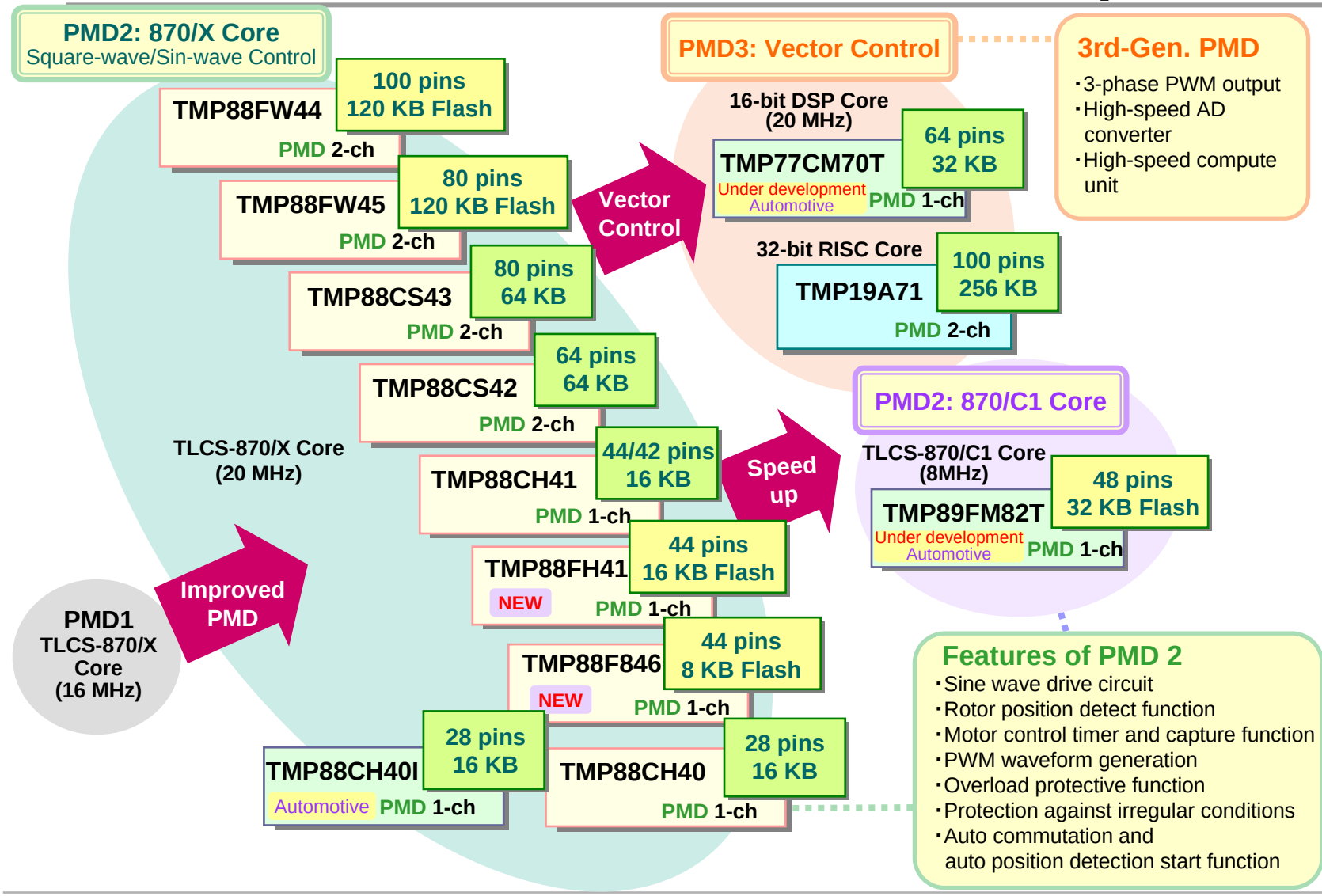
The **Programmable Motor Driver (PMD)** is a Toshiba proprietary circuit for realizing inverter control of three-phase motors.

Toshiba's **PMD** microcontrollers contain hardware for coordinating motor drive signals and feedback signals from motors, enabling them to control motors with light CPU load.

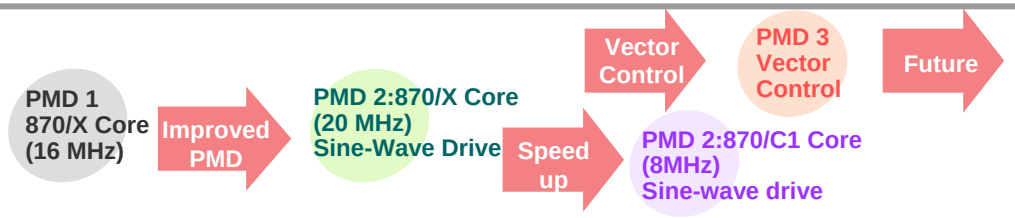
These microcontrollers are ideal for controlling three-phase brushless DC motors and three-phase AC motors in home appliances.



Toshiba PMD Microcontroller Line-up



Major Features of Toshiba PMD Microcontrollers



PMD 2: 870/X Core (20MHz)

With the inclusion of hardware components for various motor control functions such as three-phase PWM generation, rotor position sensing, a dedicated timer and motor protection, PMD 2 permits motor control with an 8-bit microcontroller. PMD 2 also allows sine-wave output with no additional burden on software, enabling motor noise reduction for washing machines and such. With the sine-wave generator, PMD 2 can easily support AC inverters.

PMD 2: 870/C1 Core (8MHz)

In accordance with the enhanced processing speed of the TLCS-870/C1 core, multiple sine-wave tables are supported. Furthermore, by setting the amplitude of a sine wave to higher than 100%, a quasi-trapezoidal wave can be generated, realizing high-power output.

PMD 3: Vector Control

PMD 3 contains a high-performance CPU and AD converter to support the motor vector control technique used in industrial inverters. PMD 3 also meets the requirements of diverse inverter-powered home electronic appliances.

Toshiba offers a wide range of PMD microcontrollers with low to high pin count.

Motor Types Supported by PMD

Motor Type	PMD 1 Square Wave Drive	PMD 2 Sine Wave Drive	PMD 3 Vector Control
Sensorless BLDC motor control (square wave) for compressors (air conditioners, refrigerators)	Suitable	Suitable	Suitable
Sensored BLDC motor control (square wave) for washing machines, air fans	Suitable	Suitable	Suitable
Sensored BLDC motor control (sine wave) for washing machines, air fans	OK **but with increased software load**	Suitable	Suitable
3-phase induction motor control (sine wave) for AC inverter products (air conditioners, refrigerators, washing machines)	OK **but with increased software load**	Suitable	Suitable
Vector control of BLDC motors/3-phase induction motors for compressors, fans	Not suitable	Not suitable	Suitable

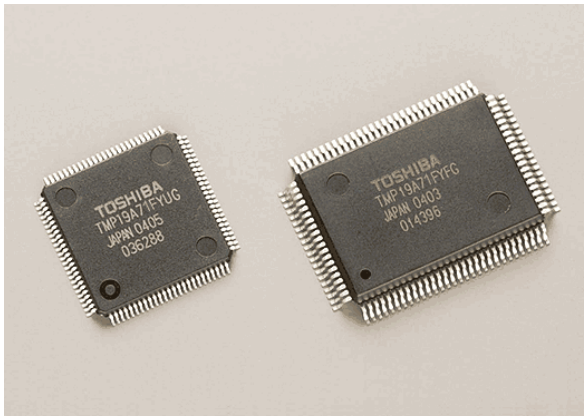
* BLDC: Brushless DC

PMD 3 Microcontrollers

PMD 3
Vector Control

In today's home appliance industry where the drive to achieve ever higher performance such as energy savings is advancing, an increasing number of motor control systems use vector control that enables high-speed and high-precision control of motor currents.

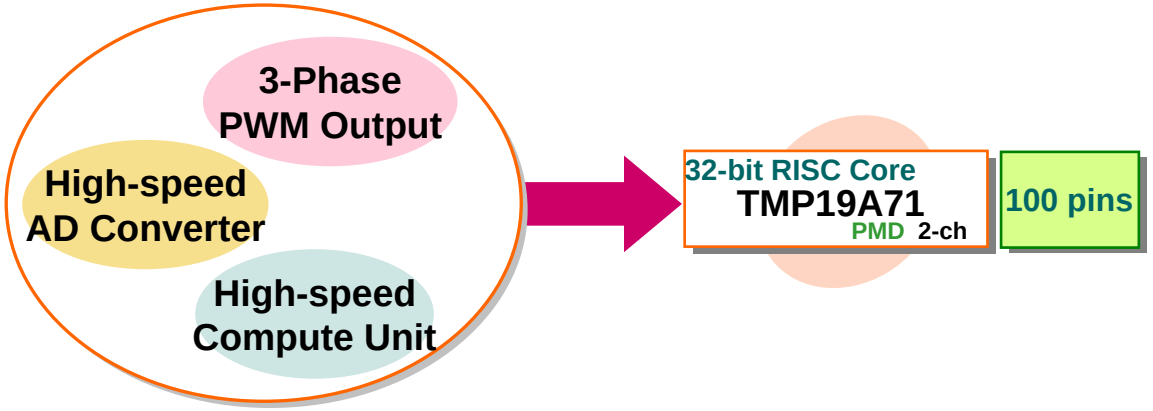
To meet this demand, Toshiba has developed the third-generation PMD containing a three-phase PWM generator, a PWM-synchronized high-speed AD converter and a high-speed multiply-accumulate (MAC) unit.



TMP19A71
(32-bit RISC core)

Features of PMD 3

Toshiba offers a variety of PMD microcontrollers for motor control.

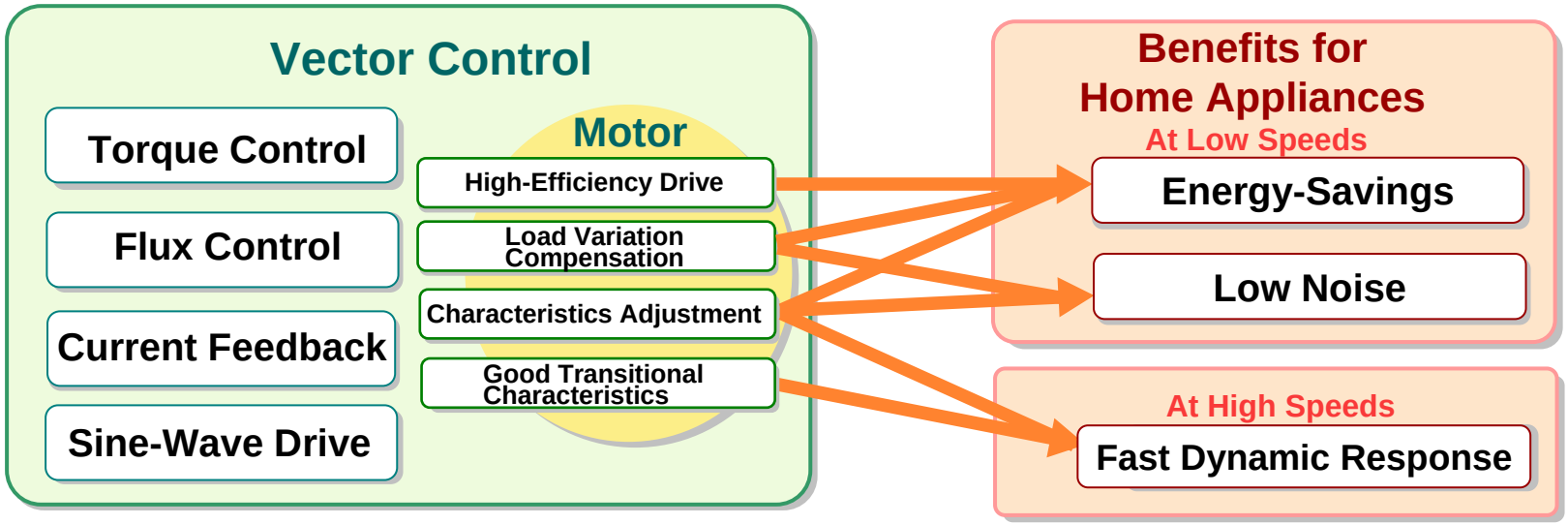


PMD 3 contains all hardware components required for motor vector control: a high-speed computational unit, a high-speed AD converter, and a three-phase PWM generator.

- The high-speed computational unit supports a single-cycle multiply-add operation, facilitating complex vector computation.
- The high-speed AD converter is synchronized to the three-phase PWM generator. Each of the three AD channels can initiate analog signal sampling at a specified trigger point. Not only 3-shunt but also 1-shunt operations are supported.

Vector Control Benefits for Home Appliances

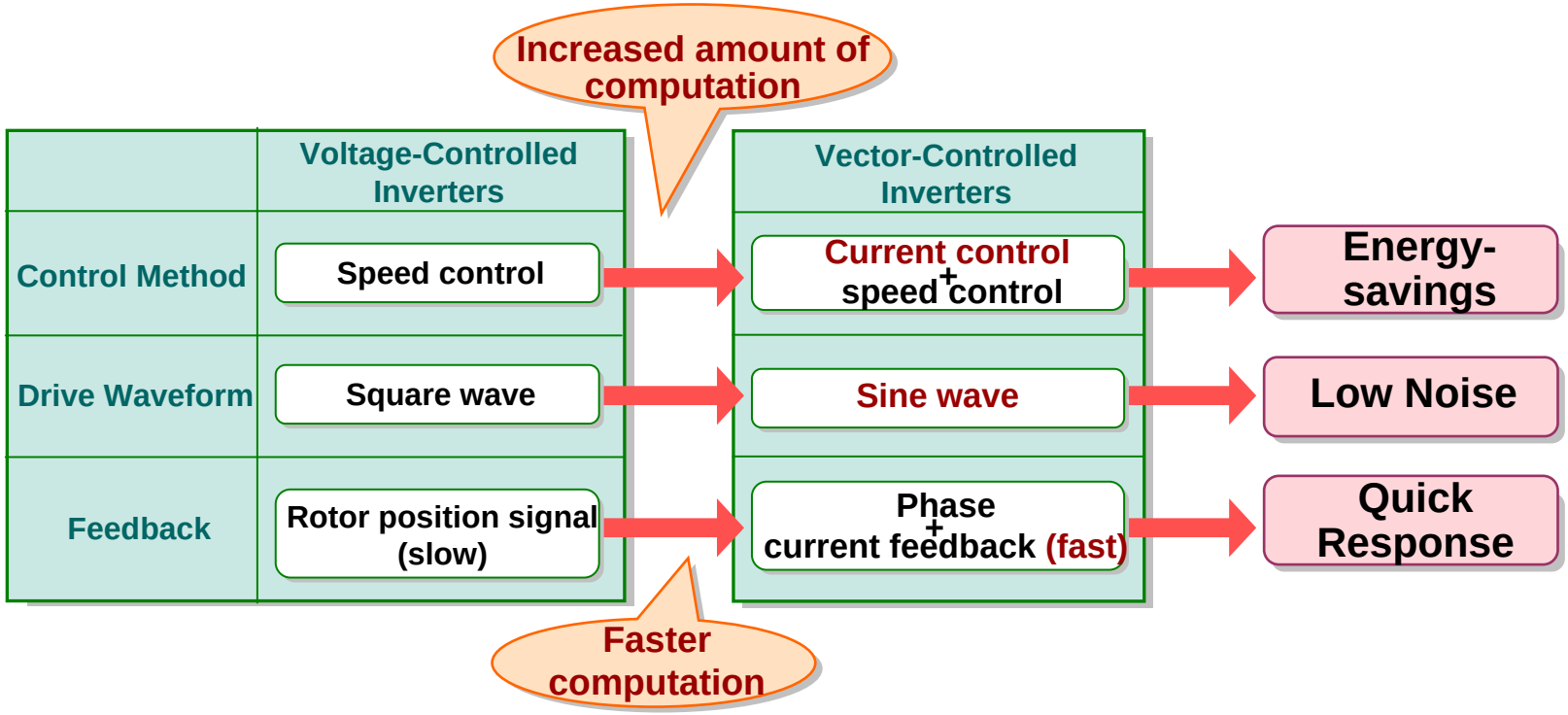
The vector control technique breaks down the motor current into magnetizing and torque-producing components and computes an optimal current level according to the rotor position. Vector control offers a number of benefits, including lower torque variation and higher efficiency, as compared to square-wave inverters. Since control is done in each PWM cycle, this technique allows precise speed regulation at low speeds, making it possible to further decrease a motor's rotation.



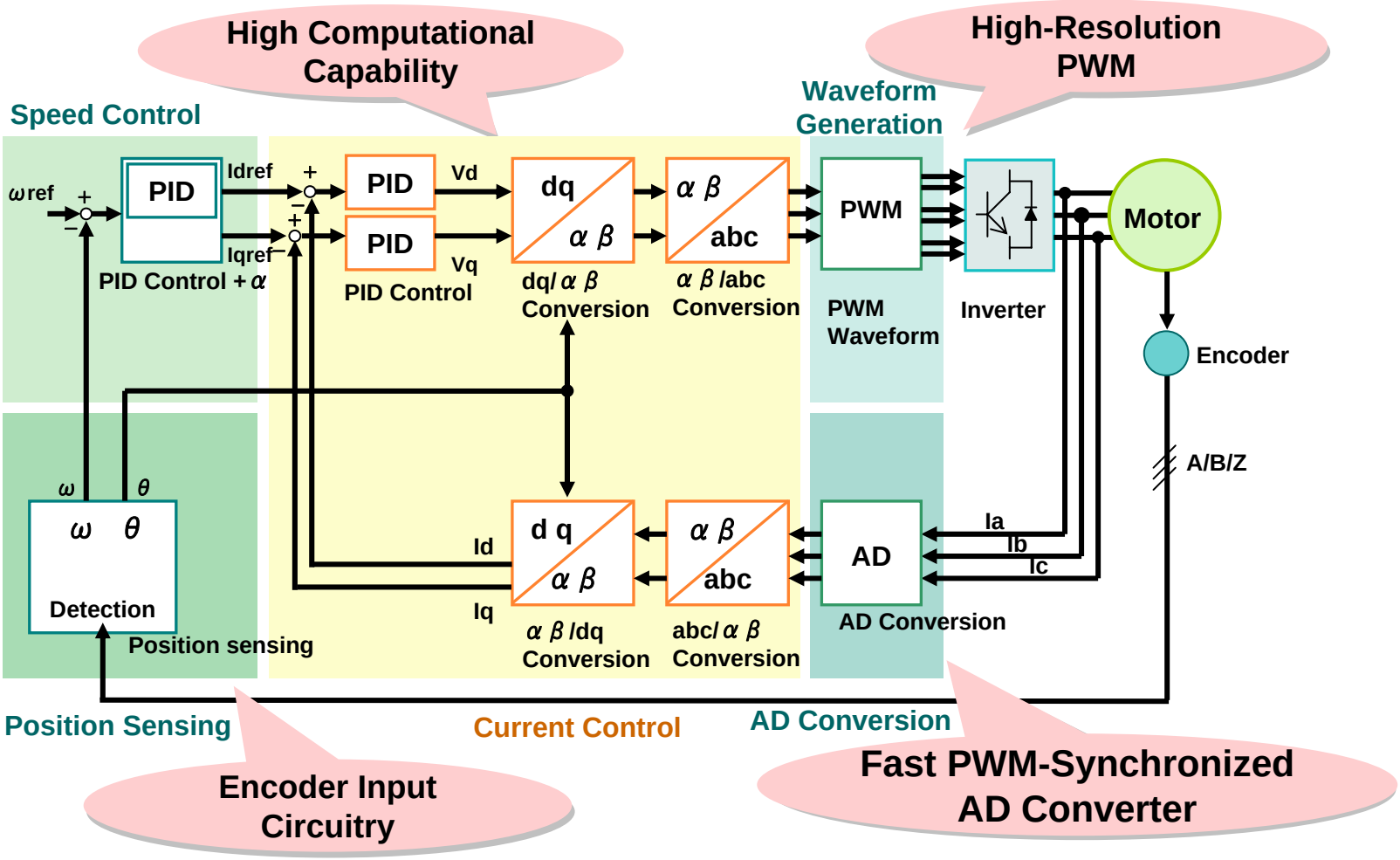
Vector control maximizes motor performance, enabling smooth and high-efficiency operations.

Traditional Motor Control vs. Vector Control

Vector control relies on current control instead of voltage control. Since current feedback is done quickly in every PWM cycle, high-efficiency control is possible for a wide range of motor speeds.

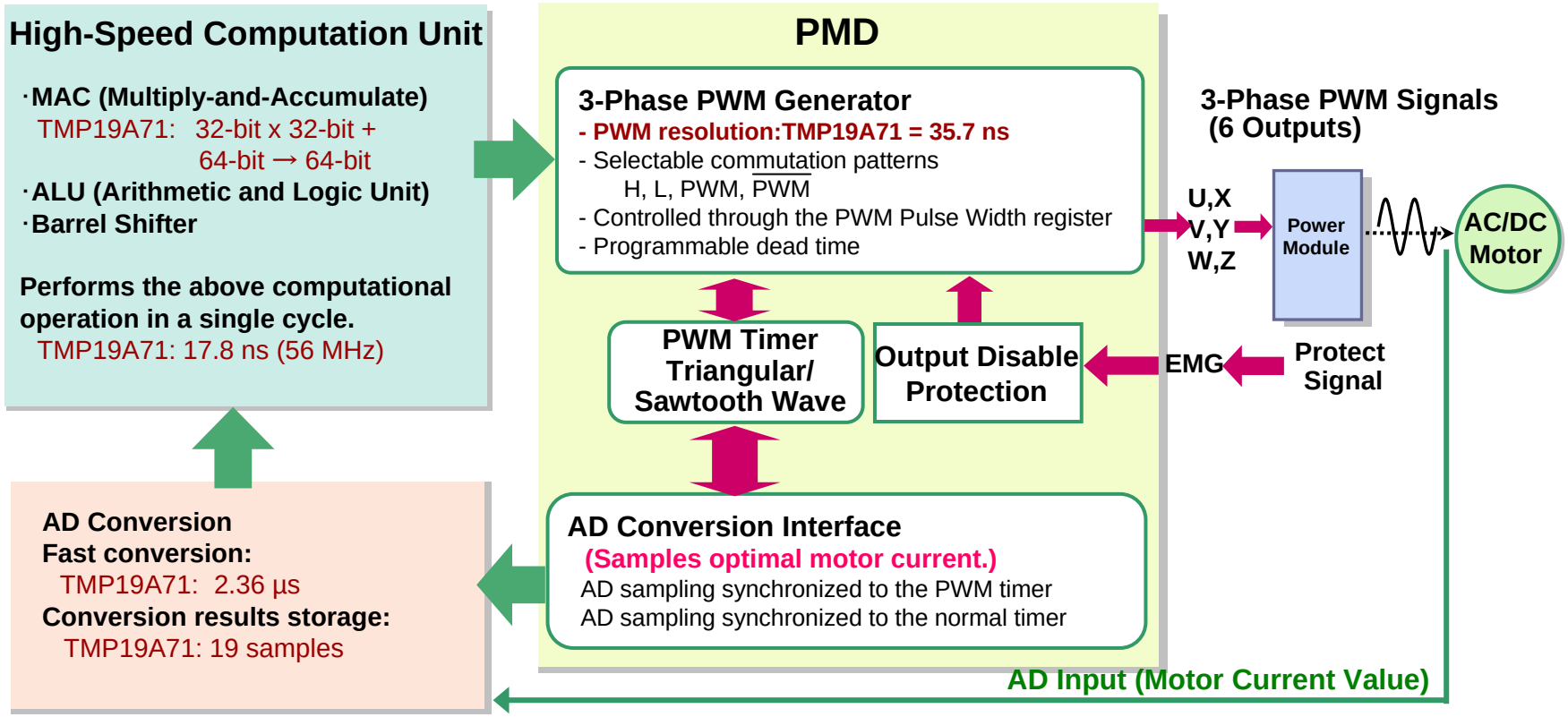


Vector Control Block Diagram



Features of PMD 3 (Details)

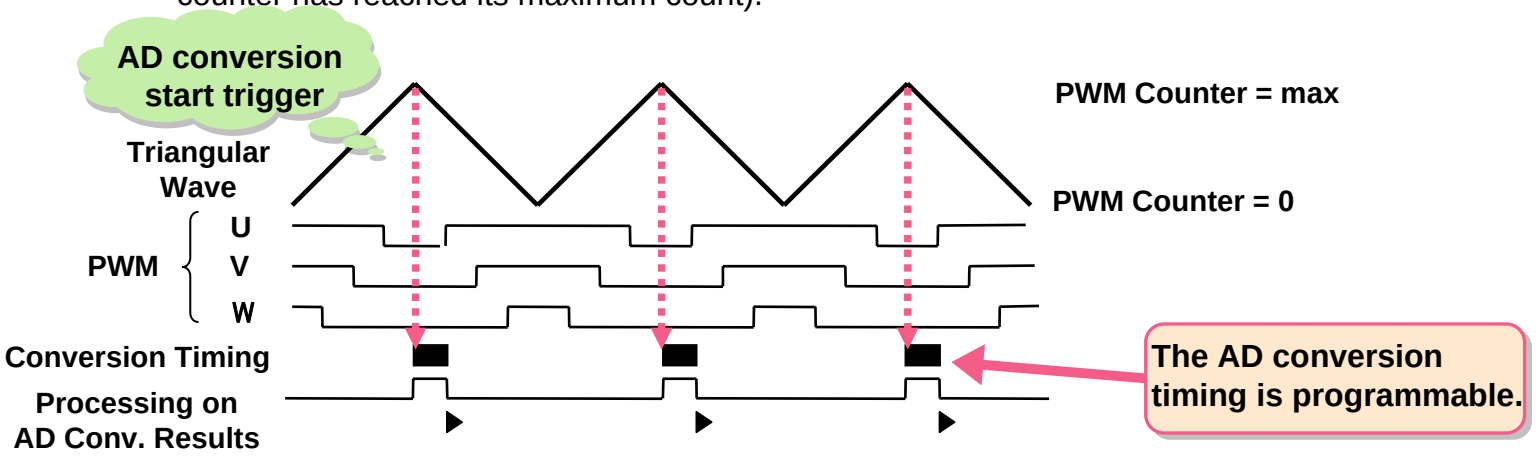
PMD 3 → The AD converter interface works in tandem with the PMD. AD conversion, arithmetic computation and three-phase PWM generation are quickly and easily controllable.



AD Converter Synchronized to the PWM Output

AD conversion example: Synchronized to the PWM peak (single sampling)

Assumption: The motor current is sampled at the center of the PWM-off period (i.e., when the PWM counter has reached its maximum count).



Synchronizing the PMD to the PWM timer

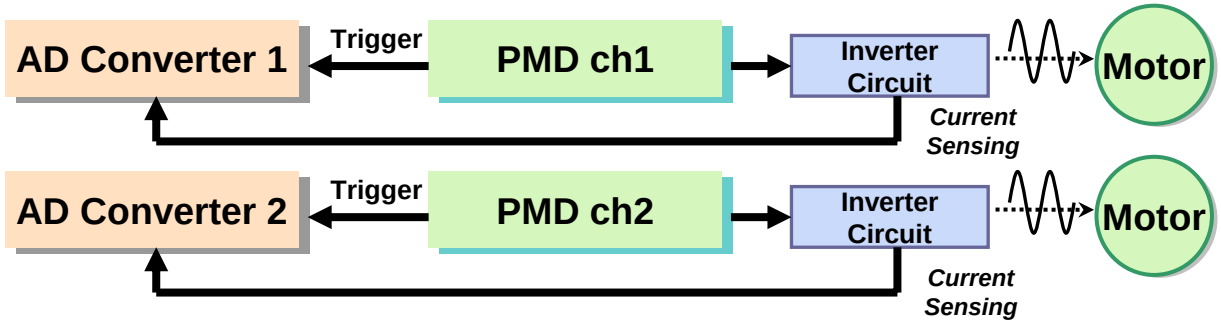
The sampling of the AD converter can be triggered at an arbitrary point within the PWM cycle; i.e., when the PWM timer has reached the peak (maximum), bottom (zero) or any programmed count.

Holding AD conversion results

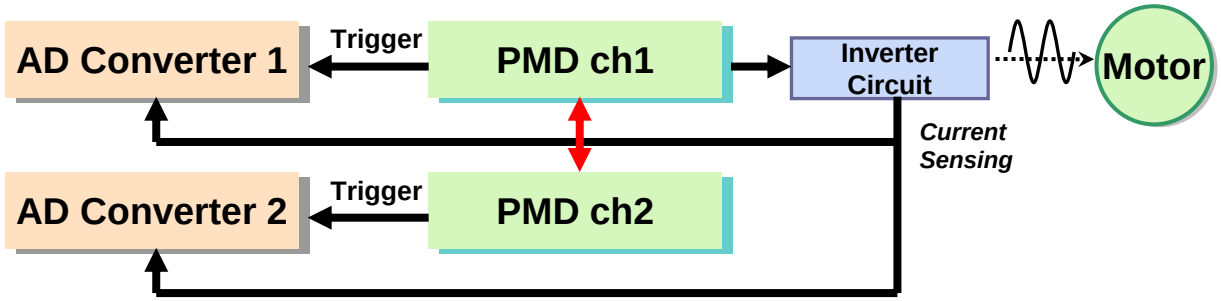
Continuous-scan sampling allows up to eight channels to be sampled continually and their conversion results to be held at a time.

Two AD Converters Capable of Simultaneous Operation

When driving two motors



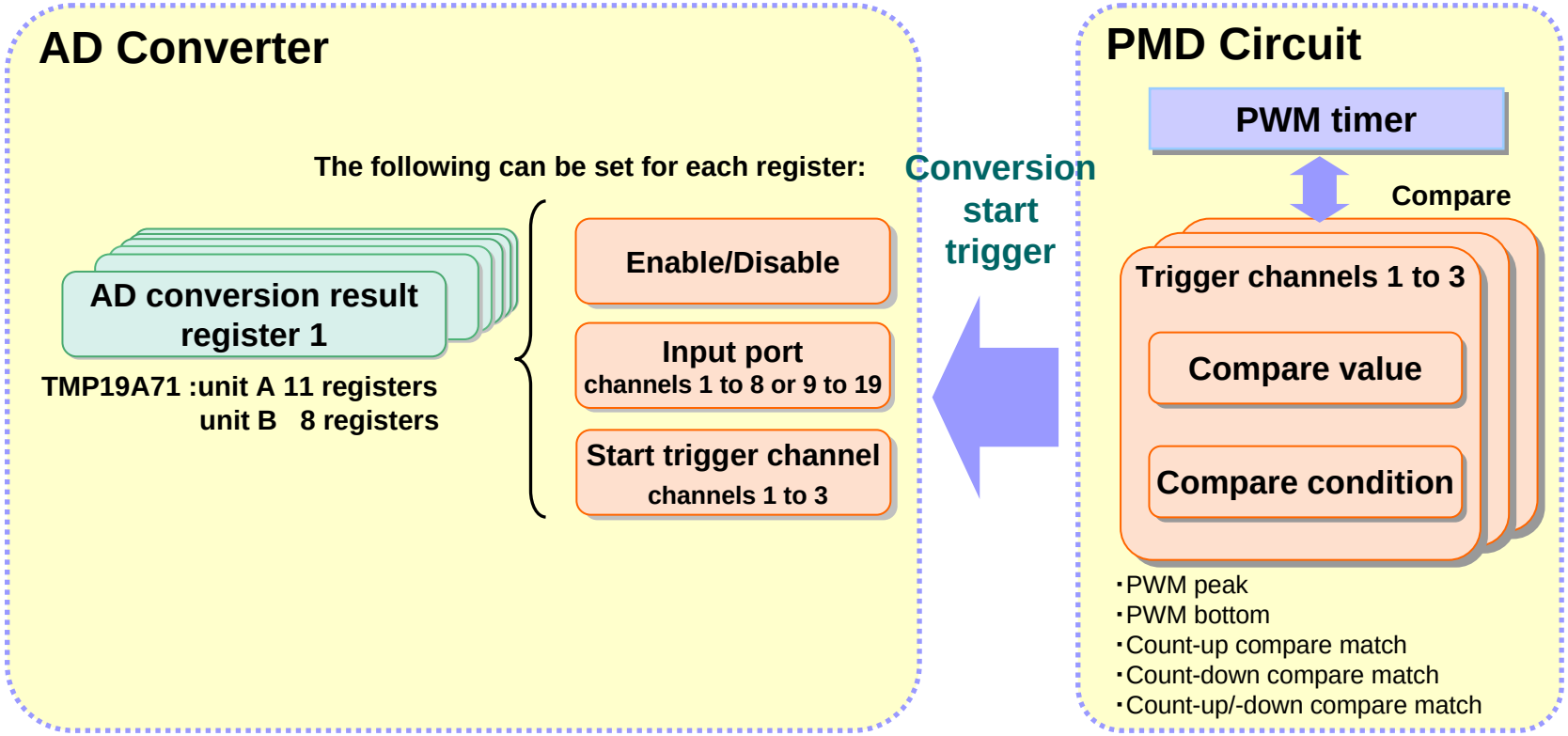
When driving one motor



PMD2 and PMD1 operate synchronously.
(PMD2 does not support external output.)

The TMP19A71 contains two motor circuits each with an AD converter, allowing vector control of two motors. In addition, by synchronizing the timers in these motor circuits, two AD converters can be used to drive a single motor. This feature is especially useful for a three-shunt motor; it enables simultaneous current measurement for two phases so that measurement accuracy can be improved.

AD Conversion Start Trigger Setting

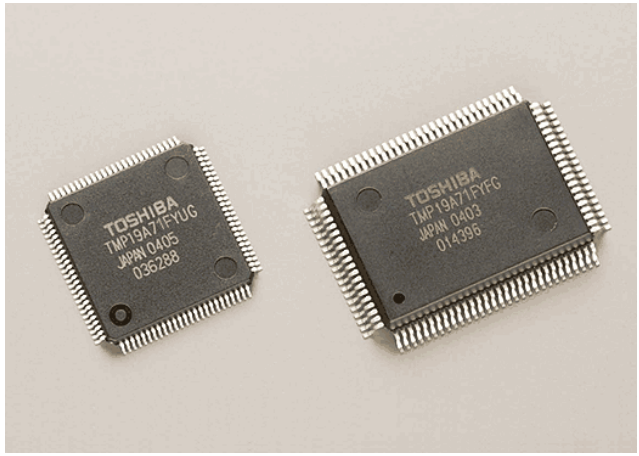


Each AD conversion result register can be enabled or disabled independently, and input port and start trigger can also be set for each register.
Each of the three trigger channels is provided with a compare register, and the AD conversion start point can be selected for each trigger channel.

TMP19A71

The **TMP19A71** is a single-chip 32-bit RISC microcontroller containing PMD 3.

Packaged in a 100-pin QFP, the microcontroller has 256 Kbytes of on-chip ROM and is capable of executing almost all operations in one clock cycle (17.8 ns at 56 MHz). These features help realize on a single chip not only vector motor control but also application control for applications such as washing machines and air conditioners (outdoor units).

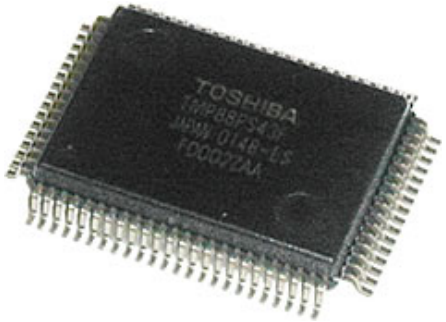


TMP19A71
(32-bit RISC core, PMD 3 Microcontrollers)

PMD 2: 870/X Core Microcontrollers

PMD2: 870/X Core
(20 MHz)
Sine-Wave Drive

The 8-bit 870/X core provides fast instruction execution at a frequency of 20 MHz. With the inclusion of hardware components for various motor control functions such as three-phase PWM generation, rotor position sensing, a dedicated timer and motor protection, the second-generation PMD permits inverter motor control with an 8-bit microcontroller. The integrated sine-wave generator allows sine-wave output with no additional burden on software, enabling motor noise reduction for washing machines and such. With the sin-wave generator, the PMD can also easily support AC inverters.



TMP88CS43FG
(PMD 2 Microcontrollers)

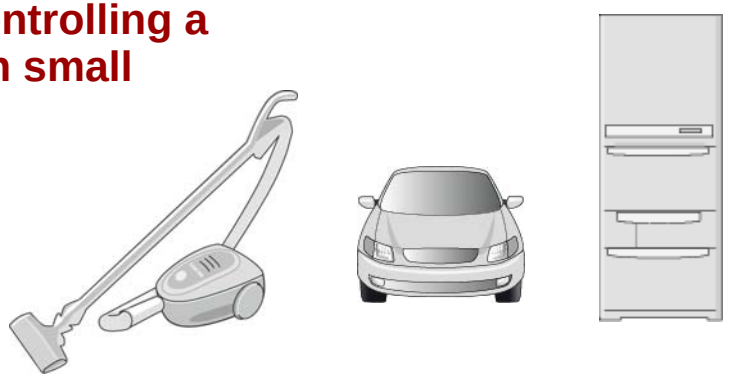
Applications of PMD 2: 870/X Core

PMD2: 870/X Core

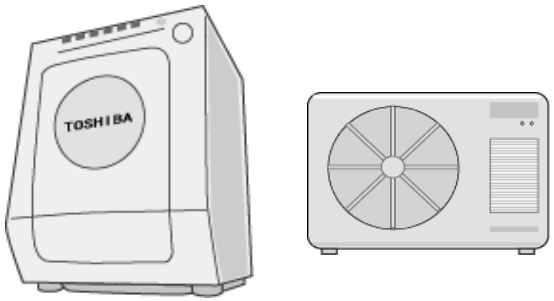
TLCS-870/X Core (20 MHz)

Mask / OTP	TMP88CH40	PMD 1-ch	28 pins
Mask / OTP	TMP88CH41	PMD 1-ch	44/42 pins
Flash	TMP88FH41	PMD 1-ch	44 pins
Flash	TMP88F846	PMD 1-ch	44 pins
Mask / OTP	TMP88CS42	PMD 2-ch	64 pins
Mask / OTP	TMP88CS43	PMD 2-ch	80 pins
Flash	TMP88FW45	PMD 2-ch	80 pins
Flash	TMP88FW44	PMD 2-ch	100 pins

Suitable for controlling a single motor in small applications

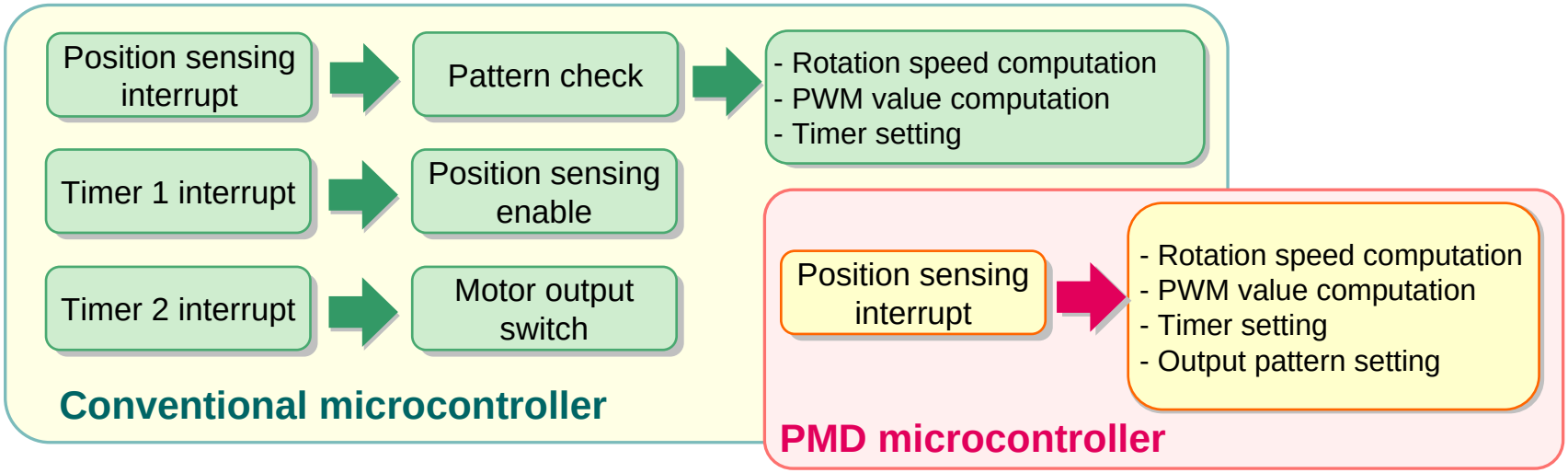


Can control all motors and system with a single chip



An appropriate motor drive method is selectable: e.g., square-wave control for sensorless DC motors, sine-wave control for DC motors with sensors, etc.

Motor Control with an 8-bit PMD Microcontroller



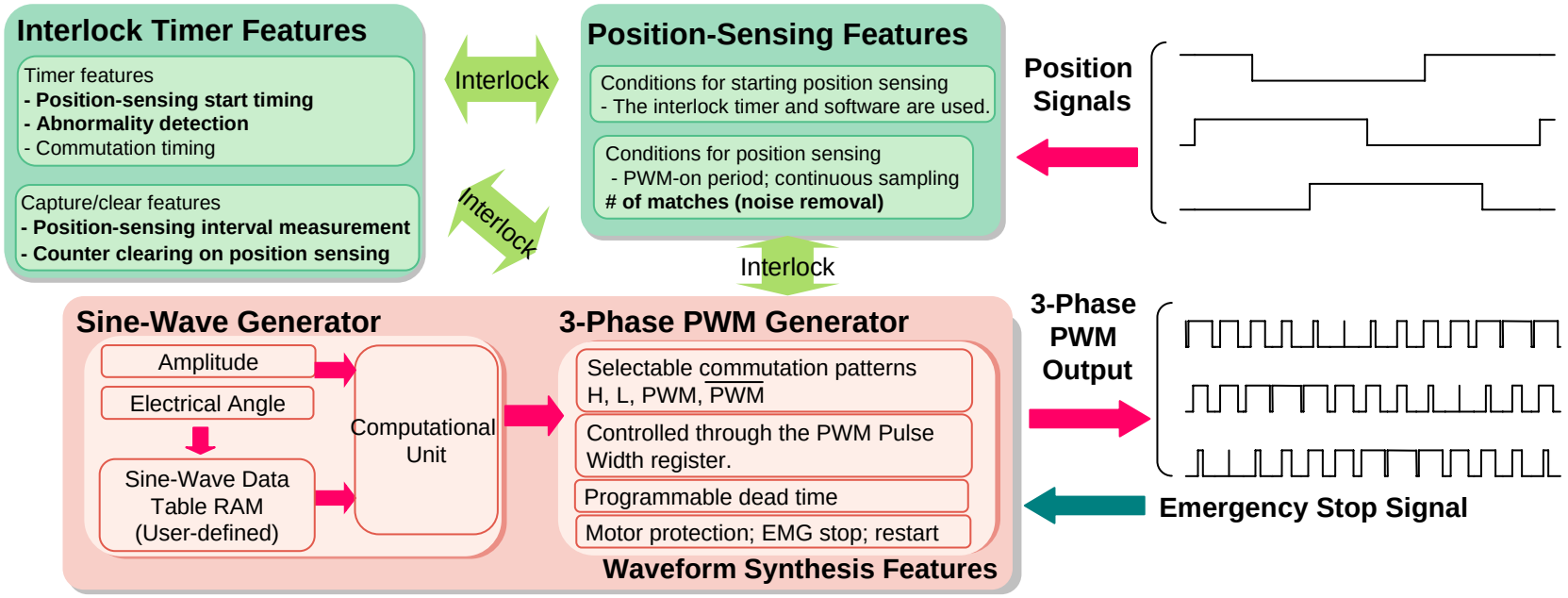
Implementing motor control functions in hardware improves program efficiency by eliminating the need for processing high-priority interrupts by software and allowing other processing to be programmed.

Hardware motor control components include a three-phase PWM generator capable of 12-bit output at a resolution of 100 ns, a sine-wave generator, an interlock timer, and a position-sensing circuit. These functions work in tandem to realize efficient inverter motor control.

Features of PMD 2: 870/X Core

Features of the PMD Microcontrollers

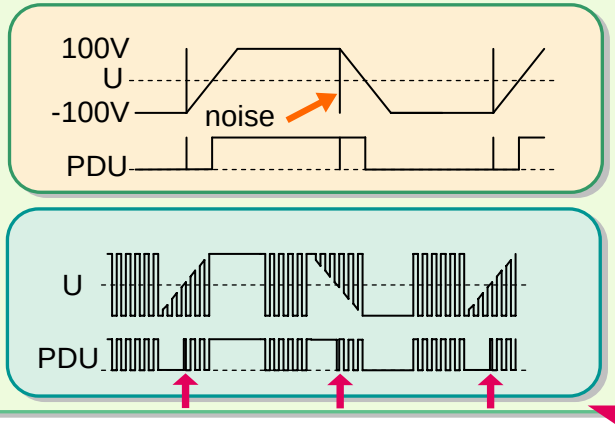
Since the PMD microcontroller contains a position-sensing circuit, an interlock timer, a three-phase PWM generator and a sine-wave generator, it is possible to create a sine wave through simple register programming.



The PMD provides efficient inverter control of a three-phase motor(s).

Position-Sensing Feature of PMD Microcontrollers

Traditional problem



For rotor position sensing for a sensorless DC motor, the midpoint of the phase voltage is fed to a comparator and its result is supplied to a microcontroller.

Since an actual motor generates a PWM signal, it is difficult to detect a correct edge, as shown at left.

Position-sensing feature of PMD microcontrollers

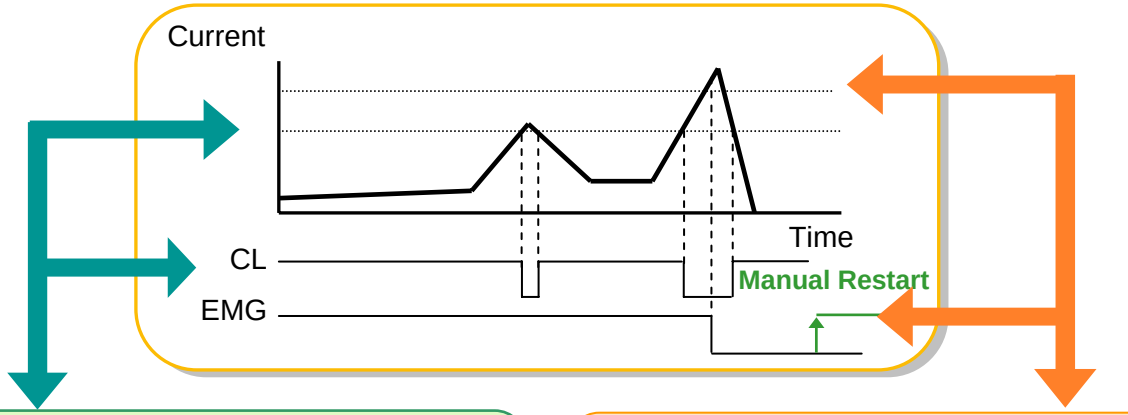
Digital sampling : Automatic sampling during PWM-on periods

Automatic sampling enable/disable : Enables or disables the interlock timer for removing commutation noise

4-bit delay time : Prevents sampling for a programmed time (Tr delay) after the PWM is turned on.

Additionally, the software burden is further reduced by four frequency options, a 4-bit chattering counter, an interlock counter and so forth. These features are suitable for position sensing for a sensorless DC motor.

Two Safety Features: Overload Protection Input and Emergency Stop Input



The CL input is driven low when more-than-normal current is detected, for example, due to overload.

When CL = low, the PMD stops generating PWM signals. (The off-phase is selectable.) Meanwhile, the PMD remains active. The PWM output can be restarted by one of two ways: timer or PWM-synchronous.

The EMG input is forced to low when an excessive inrush current is detected.

When EMG = low, the entire PMD circuitry is shut down, including the PWM output. (There is no way to restart the PWM output automatically.) When EMG is released (high), the PMD becomes active.

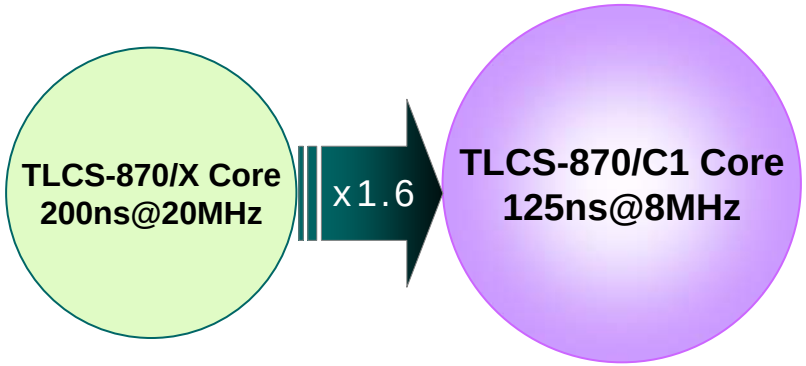
Features of PMD 2: 870/C1 Core

PMD2:870/C1 Core
(8MHz)
Sine-wave drive

870/C1 Core

◆ High-Speed Processing

The TLCS-870/C1 core is capable of executing one instruction in a single clock cycle (1.6 times faster than the TLCS-870/X core).



◆ On-Chip Debug Function

The on-chip debug function enables debugging of motor control programs on an inverter board with only simple connection.

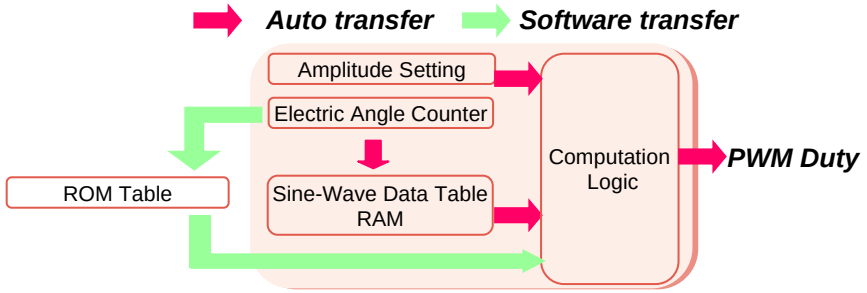
Improved PMD

◆ Improved PWM Frequency Resolution

Conventional (100ns@20MHz) → Improved (41.7ns@8MHz)

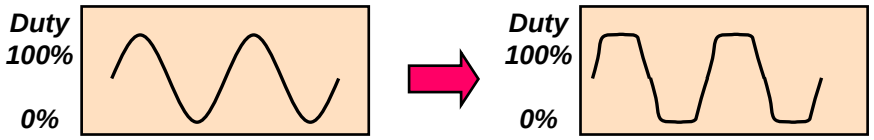
◆ Multiple Sine-Wave Tables

In addition to automatic calculation by sine-wave table RAM, sine-wave data can be transferred by software. It is thus possible to realize multiple maps.



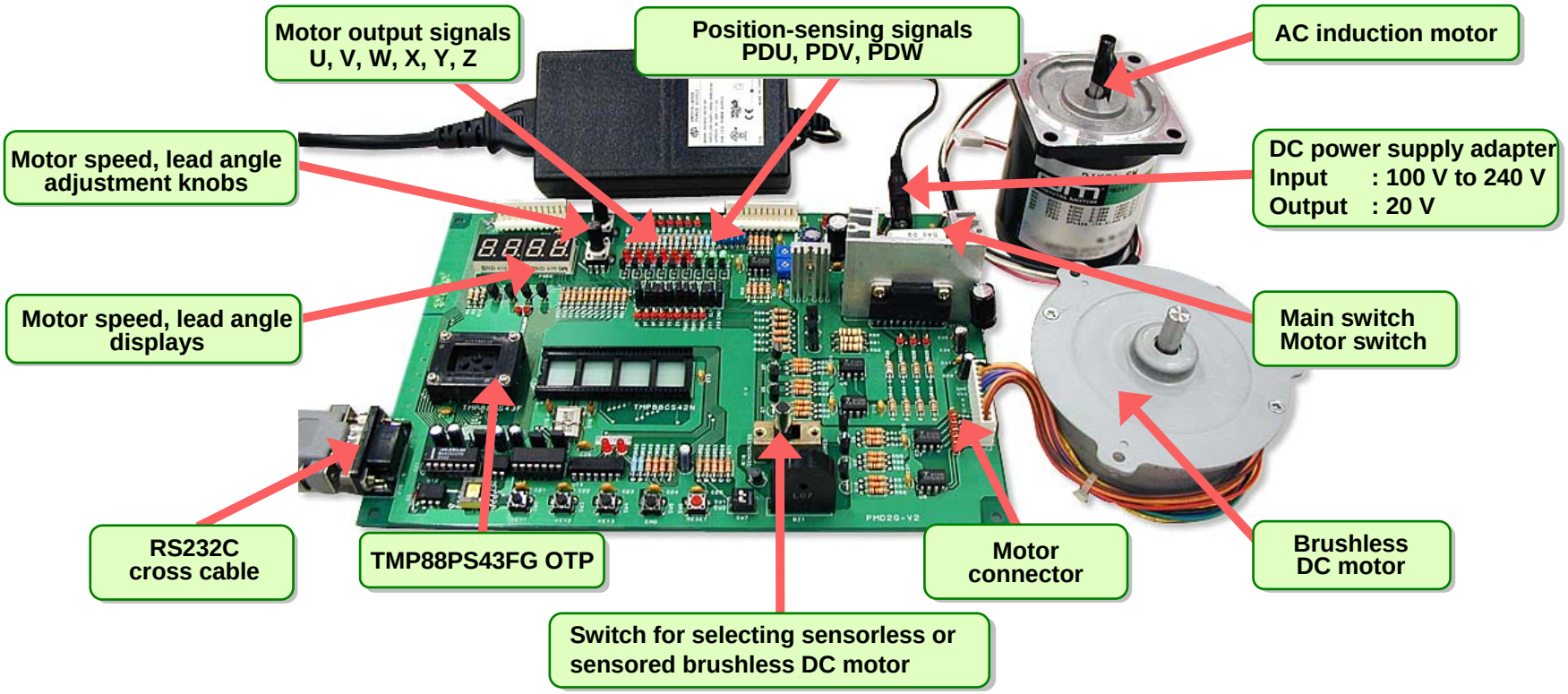
◆ Trapezoidal Wave Generation

Waveform amplitude can be set to be higher than the PWM frequency, enabling trapezoidal wave generation.



PMD Starter Board (TMP88PS43/TMP88PS42)

A low-voltage (20V) evaluation board is available, which is ideally suited for PMD beginners. We also provide motor control software supporting all the PMD microcontrollers in the TLCS-870/X Series.



Application Specifications

Application Specifications

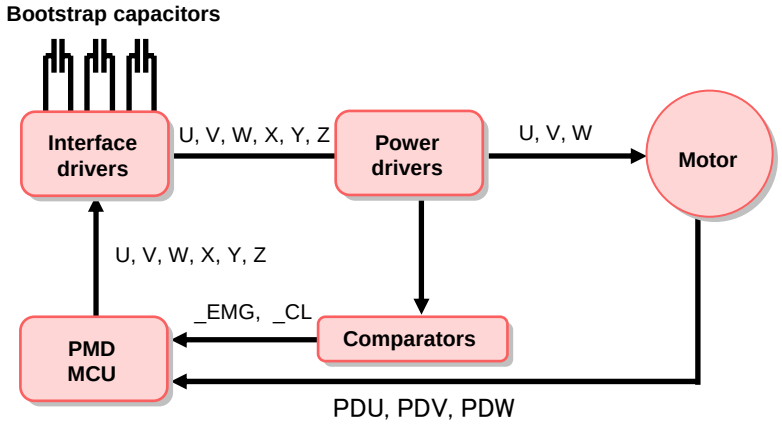
Microcontroller	TMP88PS43FG TMP88PS42NG/FG
Oscillation frequency	20 MHz
Power supply	Control: +5 V Motor drive: +20 V
Position sensing circuit	A sensorless or sensored motor can be selected with a slide switch.
Overcurrent detection	EMG signal detection, overload protection signal detection
Drive channel selection	For using one PMD channel, an internal or external driver can be selected with a jumper. It is also possible to drive two channels simultaneously using internal and external drivers.
Operation control	Motor speed and lead angle can be adjusted with knobs.
Motor output signals	Upper phase (U, V, W) and lower phase (X, Y, Z) signals can be displayed on LEDs.
Position sensing signals	The PDU, PDV, and PDW signals can be displayed on LEDs.

Motor Drive Methods

The following four types of motor drive methods are supported:

- Sensored BLDC motor sine wave drive
- Sensored BLDC motor square wave drive
- Sensorless BLDC motor square wave drive
- AC induction motor drive

(BLDC: Brushless DC)



For the sample program that can be used on this evaluation board, please contact your local Toshiba sales representative.

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