

# RX Family and M16C Family

## Guide for Migration from the M16C to the RX: A/D and D/A Converters

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### Abstract

This document describes migration from the A/D and D/A converters in the M16C Family to the A/D and D/A converters in the RX Family.

### Products

RX Family

M16C Family

When this document explains migration from the M16C Family to the RX Family, the M16C/65C Group MCU is used as an example of the M16C Family MCU, and the RX231 Group and RX660 Group MCUs are used as examples of the RX Family MCU. When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Differences in Terminology Between the RX Family and M16C Family MCUs

| Item                          | M16C Family                       | RX Family     |
|-------------------------------|-----------------------------------|---------------|
| Peripheral function registers | Special function registers (SFRs) | I/O registers |

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1. General Differences in the A/D and D/A Converters

Table 1.1 shows General Differences in the A/D Converter. Table 1.2 shows General Differences in the D/A Converter.

Table 1.1 General Differences in the A/D Converter

| Item                                  | M16C (M16C/65C)   | RX (RX231)  | RX (RX660)  |
|---------------------------------------|---|---|---|
|                                       | A/D converter   | 12-bit A/D converter  | 12-bit A/D converter  |
| A/D conversion method                 | Successive approximation  | Successive approximation  | Successive approximation  |
| Analog input voltage                  | 0 V to AVCC (3.0 to 5.5 V)  | 0 V to AVCC0 (1.62 to 5.5 V)  | 0 V to AVCC0 (1.62 to 5.5 V)  |
| Operating clock                       | f1, f1/2, f1/3, f1/4, f1/6, f1/12, fOCO40M/2, fOCO40M/3, fOCO40M/4, fOCO40M/6, or fOCO40M/12    | Peripheral module clock PCLK and A/D conversion clock ADCLK can be set so that the frequency division ratio should be one of the following. PCLK to ADCLK frequency division ratio = 1:1, 1:2, 2:1, 4:1, or 8:1 | Peripheral module clock PCLKB and A/D conversion clock ADCLK can be set so that the frequency division ratio should be one of the following. PCLK to ADCLK frequency division ratio = 1:1, 1:2, 2:1, or 4:1 |
| Resolution                            | 10-bit  | 12-bit  | 12-bit  |
| Operating modes                       | One-shot mode<br>Repeat mode<br>Single sweep mode<br>Repeat sweep mode 0<br>Repeat sweep mode 1 | Single scan mode<br>Continuous scan mode<br>Group scan mode<br>(Double-trigger mode selectable)   | Single scan mode<br>Continuous scan mode<br>Group scan mode<br>(Double-trigger mode selectable)   |
| Analog input pins                     | 26<br>• AN0 to AN7<br>• AN0_0 to AN0_7<br>• AN2_0 to AN2_7<br>• ANEX0 and ANEX1                 | 16<br>• 16 analog input pins  | 24<br>• 24 analog input pins  |
| Internally generated Analog input     | —   | • One for the temperature sensor<br>• One for the internal reference voltage  | • One for the temperature sensor<br>• One for the internal reference voltage<br>• One for the self-diagnosis function   |
| Conditions to start A/D conversion    | • Software trigger<br>• External trigger *2   | • Software trigger<br>• Asynchronous trigger (ADTRG0# pin) *1<br>• Synchronous trigger (triggers from the MTU, ELC, and temperature sensor)   | • Software trigger<br>• Asynchronous trigger (ADTRG0# pin) *1<br>• Synchronous trigger (triggers from the MTU, ELC, and TMR)  |
| Sample and hold function              | Available   | Available   | Available   |
| Low power consumption                 | —   | Module can be set to the module stop state  | Module can be set to the module stop state  |
| A/D-converted value addition function | —   | Available   | Available   |
| Self-diagnosis function               | Open-circuit detection assist function  | Self-diagnosis function, analog input disconnection detection assist function   | Self-diagnosis function, analog input disconnection detection assist function   |

| Item                | M16C (M16C/65C)   | RX (RX231)   | RX (RX660)   |
|---------------------|---|--|--|
|                     | A/D converter   | 12-bit A/D converter   | 12-bit A/D converter   |
| Event link function | —   | A/D conversion can be started when an event signal is input.   | A/D conversion can be started when an event signal is input.   |
| Interrupts          | A/D conversion interrupt  | A/D scan end interrupt (S12ADI0)<br>A/D scan end interrupt specially for group B (GBADI)   | A/D scan end interrupt (S12ADI, S12GBADI, or S12GCADI)<br>Compare interrupt (S12CMPAI or S12CMPBI)   |
| Conversion cycle    | 1.6 μs<br>(per channel, when φAD = 25 MHz)  | 1.0 μs<br>(per channel, when ADCLK = 50 MHz)   | 0.9 μs<br>(per channel, when ADCLK = 60 MHz)   |
| Error               | <ul style="list-style-type: none"> <li>Integral nonlinearity error AN0 to AN7, AN0_0 to AN0_7 input: ±3 LSB (maximum)<br/>ANEX0, ANEX1 input: ±3 LSB (maximum)</li> </ul> Example when using 3.3 V:<br>Error of ±9.668 mV (maximum)<br>*3 | <ul style="list-style-type: none"> <li>DNL differential nonlinearity error ±1 LSB (typical)</li> <li>INL integral nonlinearity error ±1 LSB (typical), ±3 LSB (maximum)</li> </ul> Example when using 3.3 V:<br>Error of ±2.417 mV (maximum)<br>*3 | <ul style="list-style-type: none"> <li>DNL differential nonlinearity error ±1 LSB (typical)</li> <li>INL integral nonlinearity error ±1.5 LSB (typical), ±2.5 LSB (maximum)</li> </ul> Example when using 3.3 V:<br>Error of ±2.014 mV (maximum)<br>*3 |

- Notes:
1. If an asynchronous trigger is input during A/D conversion, A/D conversion continues.
  2. If an external trigger is input during A/D conversion, the current A/D conversion is halted, and A/D conversion starts again.
  3. The voltage calculated assumes the conditions listed in the Electrical Characteristics – the actual error may vary.

Table 1.2 General Differences in the D/A Converter

| Item                               | M16C (M16C/65C) | RX (RX231)  | RX (RX660)  |
|------------------------------------|-----------------|---|---|
| Resolution                         | 8-bit           | 12-bit  | 12-bit  |
| D/A conversion on channels 0 and 1 | —               | Independently controlled or single whole controlled <b>can be selected</b>                      | Independently controlled or single whole controlled <b>can be selected</b>                      |
| Selectable formats                 | —               | Data format <b>can be selected</b> as flush with the right end or left end of the data register | Data format <b>can be selected</b> as flush with the right end or left end of the data register |
| Analog output pins                 | 2: DA0 and DA1  | 2: DA0 and DA1  | 2: DA0 and DA1  |
| Low power consumption              | —               | <b>Module can be set to the module stop state</b>   | <b>Module can be set to the module stop state</b>   |
| Event link function                | —               | <b>D/A0 conversion can be started when an event signal is input.</b>                            | <b>D/A0 conversion can be started when an event signal is input.</b>                            |

## 2. Functional Differences in the A/D Converter

This section explains the differences in using the A/D converter to perform A/D conversion.

The explanations in this section are based on the cases where the A/D converters of the RX231 Group, RX660 Group, and M16C/65C Group MCUs operate under the conditions shown in Table 2.1.

**Table 2.1 Modes Used in A/D Converter Operating Example**

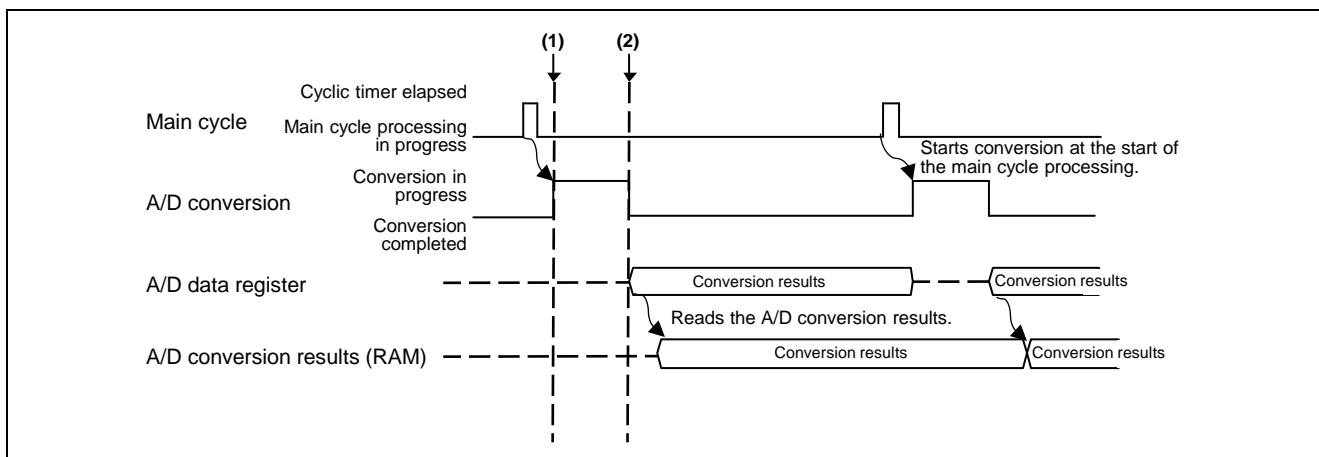
| No. | Operating Example  | M16C              | RX               |
|-----|--|-------------------|------------------|
| 1   | A/D convert the output from one sensor (refer to the operation shown in Figure 2.1)                                | One-shot mode     | Single scan mode |
| 2   | A/D convert the output from two sensors with differing responsiveness (refer to the operation shown in Figure 2.2) | Single sweep mode | Group scan mode  |

### 2.1 Example of A/D Conversion for the Output from One Sensor

This section shows an example in which the RX231 Group, RX660 Group, and M16C/65C Group MCUs operate according to the timing chart in Figure 2.1. For the modes to be used, refer to Table 2.1.

Operational example common to the RX231, RX660, and M16C/65C:

- (1) When conversion starts  
A/D conversion is started.
- (2) When A/D conversion ends  
When A/D conversion is completed, the converted value is stored in an A/D register, and an A/D conversion complete interrupt request is generated. The A/D conversion result is read in the interrupt handling.



**Figure 2.1 Timing Chart for A/D Conversion for the Output from One Sensor**

## 2.2 Example of A/D Conversion for the Outputs from Two Sensors with Differing Responsiveness

This section shows an example in which the RX231 Group, RX660 Group, and M16C/65C Group MCUs operate according to the timing chart in Figure 2.2. For the modes to be used, refer to Table 2.1.

Operational example of the RX231 and RX660:

Output from a sensor with good response is converted on A/D channel 0 using the MTU0.TGRA0 source. Output from a sensor with poor response is converted on A/D channel 1 using the MTU0.TGRB0 source.

- (1) When conversion starts  
The TGRA0 source is generated, and A/D conversion starts on A/D channel 0.
- (2) When A/D conversion on A/D channel 0 ends  
A/D conversion on A/D channel 0 is completed.
- (3) When A/D conversion on A/D channel 1 starts  
The TGRB0 source is generated approximately 150 μs after the A/D conversion start trigger, and A/D conversion starts on A/D channel 1.
- (4) When A/D conversion on A/D channel 1 ends  
A/D conversion on A/D channel 1 is completed. When all A/D conversions are completed, an interrupt request about completion of A/D conversions is generated. The A/D conversion result is read in the interrupt handling.

Operational example of the M16C/65C:

In single sweep mode, the sensor with good response uses A/D channel 0 for A/D conversion and the sensor with poor response uses A/D channel 5 for A/D conversion. A conversion wait of approximately 150 μs is secured with the conversion time for the AN0 to AN4 pins.

- (1) When conversion starts  
A/D conversion is started on A/D channel 0.
- (2) When A/D conversion on A/D channel 0 ends  
A/D conversion on A/D channel 0 is completed.
- (3) When A/D conversion on A/D channel 5 starts  
A/D conversion is started on A/D channel 5.
- (4) When A/D conversion on A/D channel 5 ends  
A/D conversion on A/D channel 5 is completed. When all A/D conversions are completed, an interrupt request about completion of A/D conversions is generated. The A/D conversion result is read in the interrupt handling.

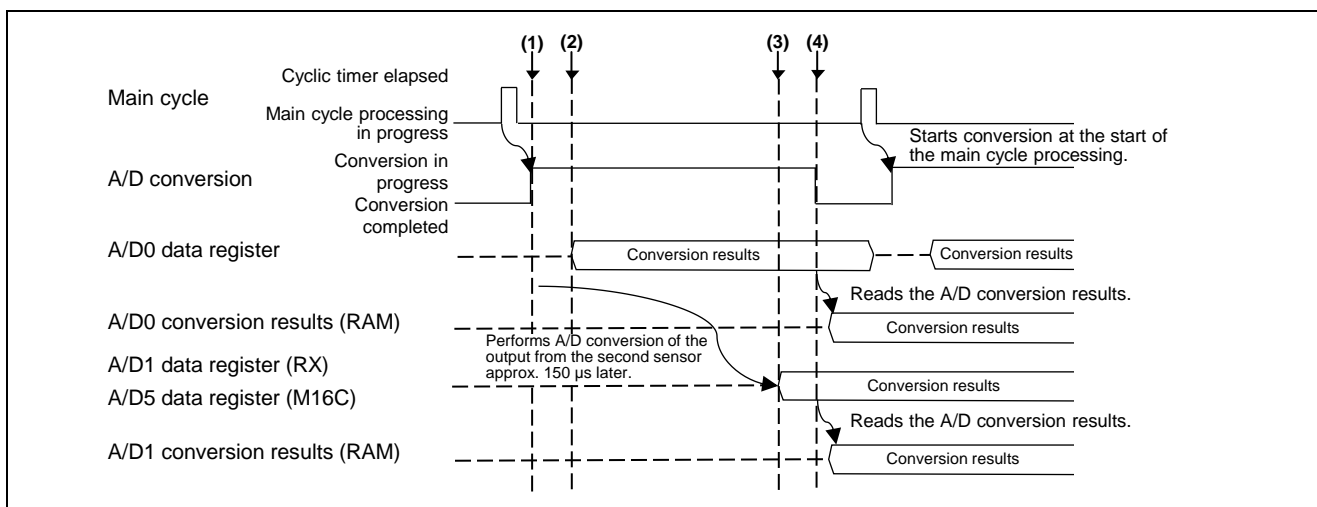


Figure 2.2 Timing Chart for A/D Conversion for the Outputs from Two Sensors with Differing Responsiveness



### 3. Appendix

#### 3.1 Points on Migration From the M16C Family to the RX Family

This chapter explains points on migration from the M16C Family to the RX Family.

##### 3.1.1 Interrupts

For the RX Family, when an interrupt request is received while all of the following conditions are met, the interrupt occurs.

- The I flag (PSW.I bit) is 1.
- Registers IER and IPR in the ICU are set to enable interrupts.
- The interrupt request is enabled by the interrupt request enable bits for peripheral functions.

Table 3.1 shows Comparison of Conditions for Interrupt Generation Between the RX and the M16C.

**Table 3.1 Comparison of Conditions for Interrupt Generation Between the RX and the M16C**

| Item                                      | M16C   | RX   |
|---|--|--|
| I flag                                    | When the I flag is set to 1 (enabled), the maskable interrupt request can be accepted.                                       |  |
| Interrupt request flag                    | When an interrupt request is generated by a peripheral function, the interrupt request flag becomes 1 (interrupt requested). |  |
| Interrupt priority level                  | Selected by setting bits ILVL2 to ILVL0.   | Selected by setting the IPR[3:0] bits.                             |
| Interrupt request enable                  | —  | Specified by setting the IER register.                             |
| Interrupt enable for peripheral functions | —  | Interrupts can be enabled or disabled in each peripheral function. |

For more information, refer to sections Interrupt Controller (ICU), CPU, and sections for other peripheral functions used in the User's Manual: Hardware.

**3.1.2 I/O Ports**

In the RX Family, the MPC must be configured in order to assign I/O signals from peripheral functions to pins.

Before controlling the input and output pins in the RX Family, the following two items must be set.

- In the MPC.PFS register, select the peripheral functions that are assigned to the appropriate pins.
- In the PMR register for I/O ports, select the function for the pin to be used as a general I/O port or I/O port for a peripheral function.

Table 3.2 shows Comparison of I/O Settings for Peripheral Function Pins Between the RX and the M16C.

**Table 3.2 Comparison of I/O Settings for Peripheral Function Pins Between the RX and the M16C**

| Function  | M16C (in the case of the M16C/65C)   | RX (in the case of the RX660/RX231)   |
|---|--|---|
| Select the pin function                                 | These are not available in the M16C. <sup>*1</sup><br>When a mode is set for a peripheral function, appropriate pins are assigned as I/O pins for the peripheral function. | With the PFS register, I/O ports for peripheral functions can be assigned by selecting from multiple pins.            |
| Switch between general I/O port and peripheral function |  | With the PMR register, the corresponding pin function can be selected as a general I/O port or a peripheral function. |

Note: 1. Register for similar functions are available in the M32C Series and R32C Series.

For more information, refer to the Multi-Function Pin Controller (MPC) and I/O port sections in the User's Manual: Hardware.

**3.1.3 Module Stop Function**

The RX Family has the ability to stop each peripheral module individually.

By transitioning unused peripheral modules to the module stop state, power consumption can be reduced.

After a reset is released, all modules (with a few exceptions) are in the module stop state.

Registers for modules in the module stop state cannot be written to or read.

For more information, refer to the Low Power Consumption section in the User's Manual: Hardware.

### 3.2 I/O Register Macros

Macro definitions listed in Table 3.3 can be found in the RX I/O register definitions (iodefine.h).

The readability of programs can be achieved with these macro definitions.

Table 3.3 shows Macro Usage Examples.

**Table 3.3 Macro Usage Examples**

| Macro                           | Usage Example  |
|---------------------------------|--|
| IR("module name", "bit name")   | <b>IR(MTU0, TGIA0) = 0 ;</b><br>The IR bit corresponding to MTU0.TGIA0 is cleared to 0 (no interrupt request is generated).                            |
| DTCE("module name", "bit name") | <b>DTCE (MTU0, TGIA0) = 1 ;</b><br>The DTCE bit corresponding to MTU0.TGIA0 is set to 1 (DTC activation is enabled).                                   |
| IEN("module name", "bit name")  | <b>IEN(MTU0, TGIA0) = 1 ;</b><br>The IEN bit corresponding to MTU0.TGIA0 is set to 1 (interrupt enabled).  |
| IPR("module name", "bit name")  | <b>IPR(MTU0, TGIA0) = 0x02 ;</b><br>The IPR bit corresponding to MTU0.TGIA0 is set to 2 (interrupt priority level 2).                                  |
| MSTP("module name")             | <b>MSTP(MTU) = 0 ;</b><br>The MTU0 Module Stop bit is set to 0 (module stop state is canceled).  |
| VECT("module name", "bit name") | <b>#pragma interrupt (Excep_MTU0_TGIA0 (vect = VECT(MTU0, TGIA0))</b><br>The interrupt function is declared for the corresponding MTU0.TGIA0 register. |

### 3.3 Intrinsic Functions

The RX Family has intrinsic functions for setting control registers and special instructions. When using intrinsic functions, include machine.h.

Table 3.4 shows Examples of Differences in the Settings of Control Registers and Descriptions of Special Instructions Between the RX and the M16C.

**Table 3.4 Examples of Differences in the Settings of Control Registers and Descriptions of Special Instructions Between the RX and the M16C**

| Item                               | Description    |                 |
|------------------------------------|----------------|-----------------|
|                                    | M16C           | RX              |
| Set the I flag to 1                | asm("fset i"); | setpsw_i (); *1 |
| Set the I flag to 0                | asm("fclr i"); | clrpsw_i (); *1 |
| Expanded into the WAIT instruction | asm("wait");   | wait(); *1      |
| Expanded into the NOP instruction  | asm("nop");    | nop(); *1       |

Note: 1. The machine.h file must be included.

#### 4. Reference Documents

##### User's Manual: Hardware

RX230/RX231 Group User's Manual: Hardware (R01UH0496EJ)

RX660 Group User's Manual: Hardware (R01UH0937EJ)

M16C/65C Group User's Manual: Hardware (R01UH0093EJ)

If you are using a product that does not belong to the RX231, RX660, or M16C/65C Group, refer to the applicable user's manual for hardware.

The latest versions can be downloaded from the Renesas Electronics website.

##### Technical Update/Technical News

The latest information can be downloaded from the Renesas Electronics website.

##### User's Manual: Development Tools

RX Family CC-RX Compiler User's Manual (R20UT3248)

M16C Series, R8C Family C Compiler Package (M3T-NC30WA)

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**REVISION HISTORY**

| Rev. | Date          | Description |   |
|------|---------------|-------------|---|
|      |               | Page        | Summary   |
| 1.00 | Sep. 16, 2014 | —           | First edition issued  |
| 2.00 | June 16, 2023 | —           | The product model of the target device for the RX MCU was changed:<br>From RX210 to RX231/RX660 |

# General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

## 1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity.

Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

## 2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

## 3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

## 4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

## 5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

## 6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between  $V_{IL}$  (Max.) and  $V_{IH}$  (Min.).

## 7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

## 8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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