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H8/300H, H8/300L Super Low Power Series

Example of Driving an MCU from a Low-Voltage Power Supply by Using a Step-Up DC/DC Converter and Start-Up IC

Introduction

A minimum operating voltage applies to LSI circuits in general, and not just to the Super Low Power Series. Operation will not proceed when the power-supply voltage is at a lower value. However, constraints of the following types may apply, according to the system.

- Power-supply voltages can fall because batteries are drained.
- Operation with a small solar panel may necessitate operation with a low power-supply voltage.

To satisfy such constraints, examples of using a step-up circuit to drive an MCU are introduced in this application note.

Contents

1. Step-Up Circuit

In this application note, a switching regulator with an on-chip FET for step-up PWM control (S-8353 Series) and a charge-pump IC with super-low-voltage operation for starting up step-up DC/DC converters (S-882Z Series), both manufactured by Seiko Instruments Inc., are used in a step-up circuit.

Normally, a circuit will be drivable by a step-up DC/DC converter on its own. However, using the charge-pump IC with super-low-voltage operation to start the converter up allows the operation of circuits from even lower power-supply voltages (as low as 0.3 V). More detailed descriptions of the ICs used in the step-up circuit follow.

1.1 Switching Regulator with On-Chip Step-Up PWM Control FET: S-8353 Series

The S-8353 Series is a CMOS step-up switching regulator, the main components of which are a reference-voltage source, oscillator circuit, power MOS FET, error amplifier, phase compensation circuit, and PWM control circuit.

Configuring a step-up switching regulator simply requires the addition of an external coil, capacitor, and diode.

Low-voltage operation:	Startup at 0.9 V (I_{OUT} = 1 mA) guaranteed
Low current drawn:	18.7 µA (3.3 V, 50 kHz, typ.) during operation
	0.5 µA (max.) during shutdown
Duty cycle:	On-chip PWM control circuit
	0% to 83% (30-kHz and 50-kHz models)
	0% to 78% (250-kHz models)
External parts:	Coil, capacitor, and diode
Output voltage:	Selectable in 0.1-V steps between 1.5 and 6.5 V (for separate V_{DD}/V_{OUT} types)
	Selectable in 0.1-V steps between 2.0 and 6.5 V (for types without separate V_{DD}/V_{OUT})
Oscillation frequency:	30 kHz, 50 kHz, and 250 kHz selectable
Soft-start function:	6 ms (50 kHz, typ.)

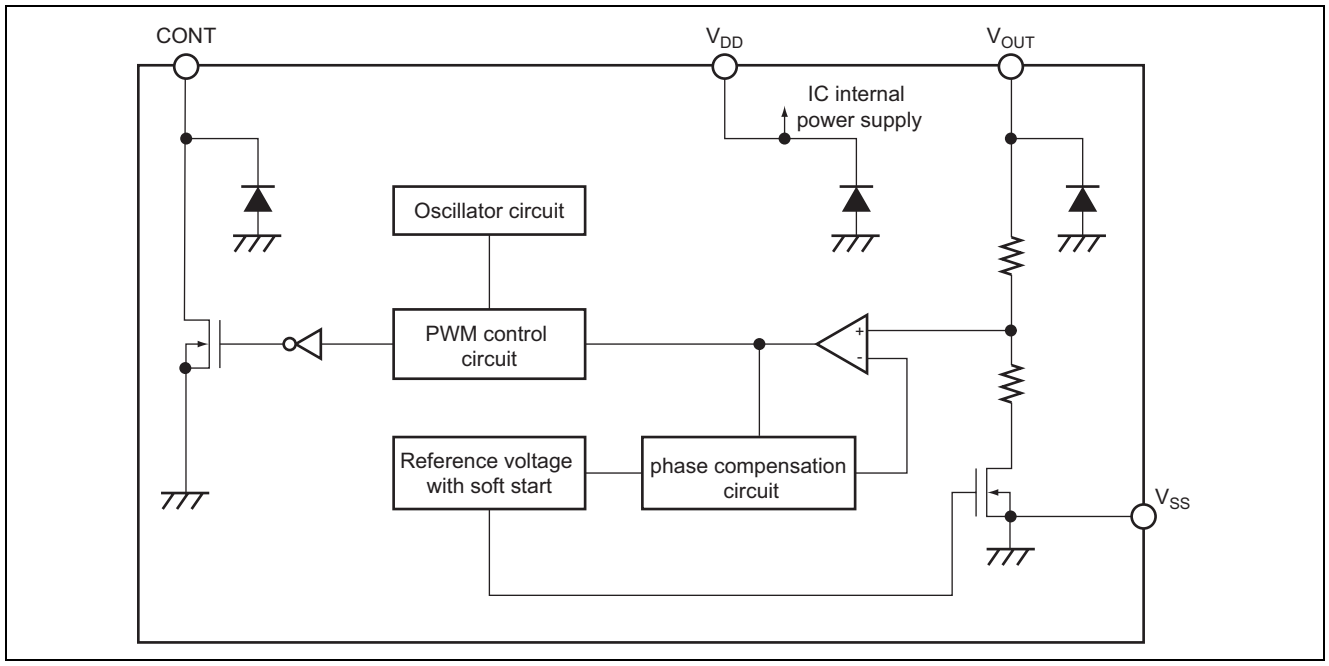


Figure 1 Block Diagram of S-8353 Series

1.2 Charge-Pump IC with Super-Low-Voltage Operation for Starting up Step-Up DC/DC Converters: S-882Z Series

The S-882Z Series differs from conventional charge-pump ICs that fully depleted SOI (silicon on insulator) technology is applied to produce a charge-pump IC for starting up step-up DC/DC converters which enables operation at super low voltages. Since they are capable of stepping up extremely low input voltages in the 0.3- to 0.35-V range, this series enables the effective usage of very weak energy sources. The stepped up electric power is stored in the startup capacitor. After this capacitor reaches the discharge-start voltage, it is discharged to provide power to start up the step-up DC/DC converter.

Operating input voltage	0.3 to 3.0 V
Current drawn:	0.5 mA max. (at V_{IN} = 0.3 V) during operation
	0.6 µA max. (at V_{IN} = 0.3 V) during shutdown
Discharge-start voltage:	1.8 to 2.4 V (selectable in 0.2 V steps)
Shutdown voltage:	Discharge-start voltage + 0.1 V (fixed)
Oscillation frequency:	350 kHz typ. (at V_{IN} = 0.3 V)
Small package:	SOT-23-5 package
External component:	startup capacitor (C_{POUT}). 1 unit*

Note *: A Schottky diode or power-smoothing capacitor may also be required, according to the values of the output-smoothing capacitor for the step-up DC/DC converter and of the output voltage.

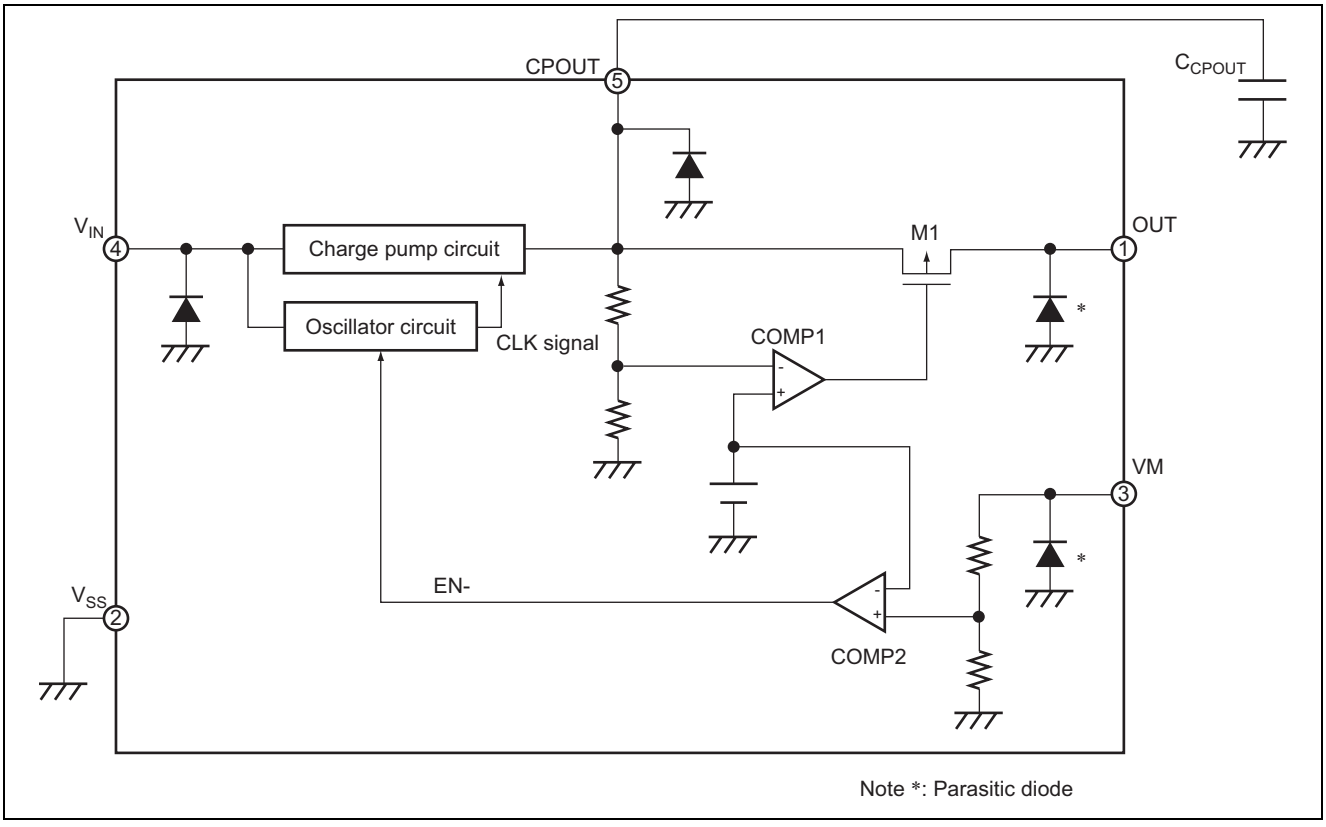


Figure 2 Block Diagram of S-882Z

1. In the S-882Z Series, input of a power-supply voltage of 0.3 V or more to the V_{IN} pin makes the oscillator start operation, producing the CLK signal as an output signal.
2. This CLK signal drives the charge pump, and the power from the V_{IN} pin is converted to stepped-up electrical power in the charge-pump circuit.
3. The stepped-up electric power output from the charge pump circuit gradually charges to the startup capacitor (C_{CPOUT}) connected to the CPOUT pin, the voltage on the pin gradually rises.
4. When the CPOUT pin voltage (V_{COUT}) reaches or exceeds the discharge-start voltage (V_{CPOUT1}), the output signal of the comparator (COMP1) changes from high to low level. This switches the discharge-control switch (M1) from off to on.
5. When M1 is switched on, the step-up electric power stored in C_{CPOUT} is discharged from the OUT pin.
6. When discharging proceeds until V_{CPOUT} falls to the level of the discharge-stop voltage (V_{CPOUT2}), M1 is switched off, and the discharge is stopped.
7. When the VM pin voltage (V_{VM}) reaches or exceeds the shutdown voltage (V_{OFF}), the output signal (EN-) of the comparator (COMP2) changes from low level to high. This makes the oscillator circuit stop, and the device enters the shutdown state.
8. When V_{VM} does not reach or exceed V_{OFF}, the step-up electric power from the charge-pump circuit reaches C_{CPOUT} again (from here, return to the step 3).

Note: When discharge to the OUT pin stops and recharging of the startup capacitor (C_{CPOUT}) is restarted, C_{CPOUT} must be charged until the voltage on the CPOUT pin (C_{CPOUT}) falls below the discharge-stop voltage (V_{CPOUT2}). In this case, the following condition must be met:

Condition: OUT pin voltage (V_{OUT}) < Discharge-stop voltage (V_{CPOUT2}).

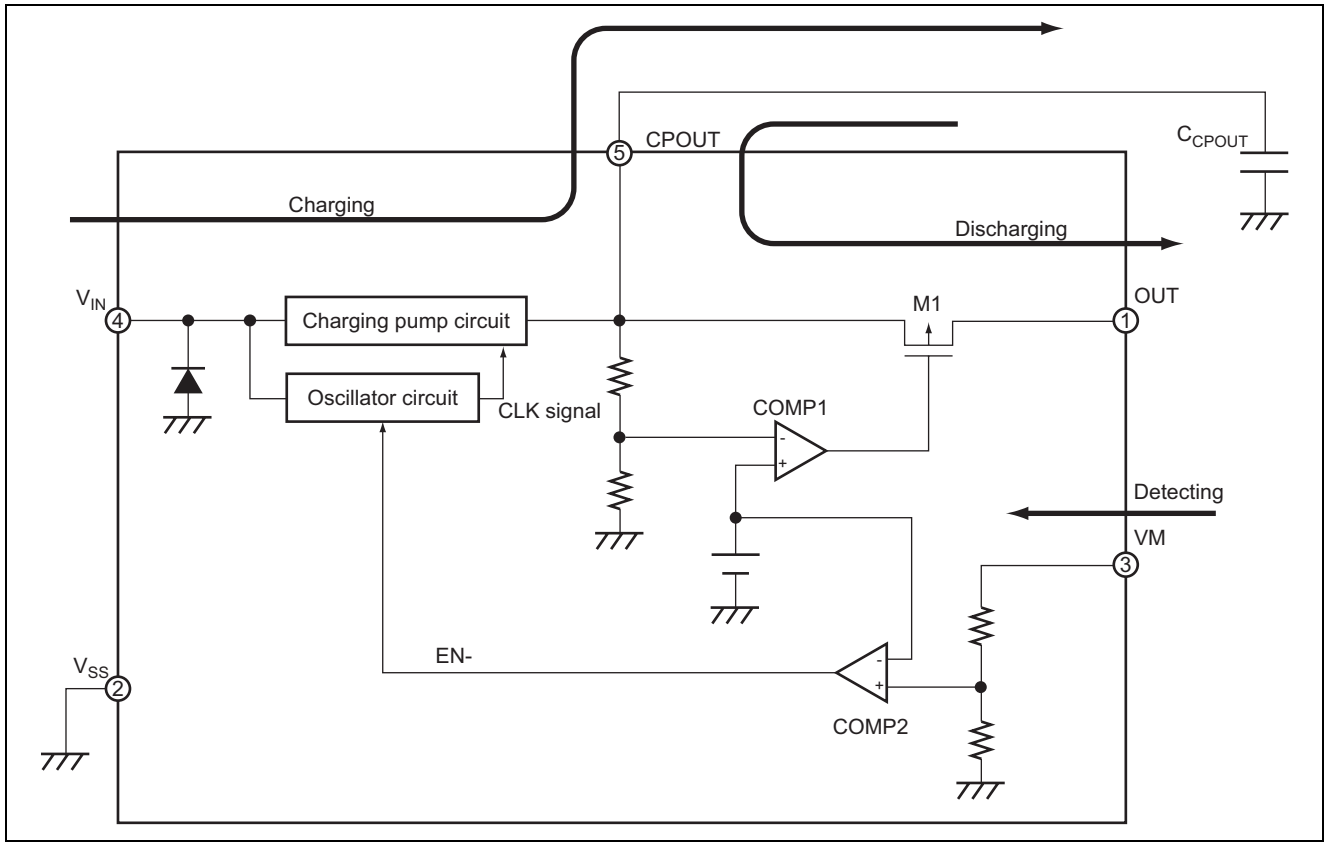


Figure 3 Example of Operation for S-882Z Series

2. Example of Using a Step-Up DC/DC Converter to Drive an MCU

In the example given below, the switching regulator with on-chip step-up PWM control FET (S-8353 Series) and charge-pump IC with super-low-voltage operation for starting up step-up DC/DC converters (S-882Z Series) are combined to drive a Super Low Power Series MCU from an input voltage of 0.3 V.

Figure 4 shows the connections between the MCU and the S-8353 Series and S-882Z Series devices.

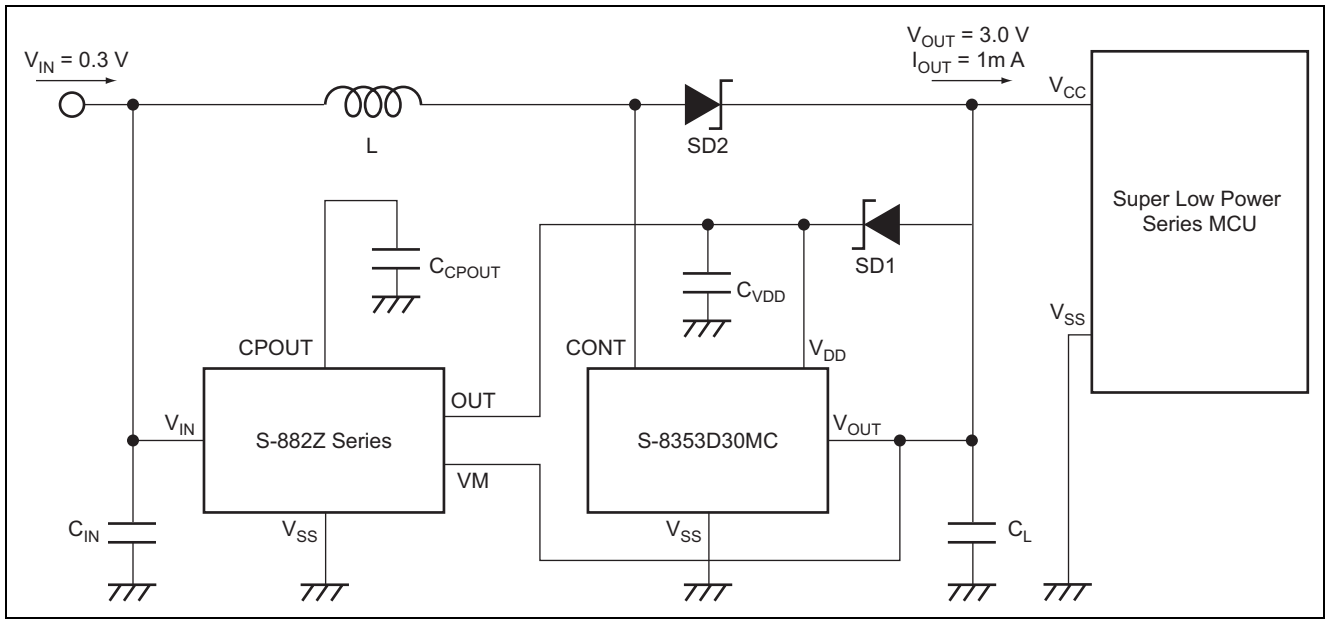


Figure 4 Example of Using a Step-Up Circuit to Drive an MCU

Table 1 shows the major parts used.

Table1 Major Parts Used

Part Name	Symbol	Manufacturer	Part No.
Super Low Power Series MCU	—	Renesas Technology Corp.	(Various; depends on the products)
S-882Z Series	—	Seiko Instruments Inc.	S-882Z20-M5T1G (Discharge-start voltage setting: 2.0 V)
Step-up DC/DC converter	—	Seiko Instruments Inc.	S-8353D30MC (Output voltage setting: 3.0 V)
Inductor	L	Sumida Corporation	CDRH5D18-101 (100 µH)
Schottky diode	SD1, SD2	Rohm Co., Ltd.	RB551V-30
Startup capacitor	C_{CPOUT}	—	10 µF (ceramic type)
Input capacitor	C_{IN}	—	47 µF
Output capacitor	C_L	—	33 µF (ESR ≥ 50 mΩ)
Power smoothing capacitor	C_{VDD}	—	1 µF (ceramic type)

Note: Following the above connection diagram and constants does not guarantee successful operation. Set the actual constants after thoroughly evaluating operation with the actual application.

The above figure shows an application circuit example with targeted values of V_{IN} = 0.3 V, V_{OUT} = 3.0 V, and I_{OUT} = 1 mA.

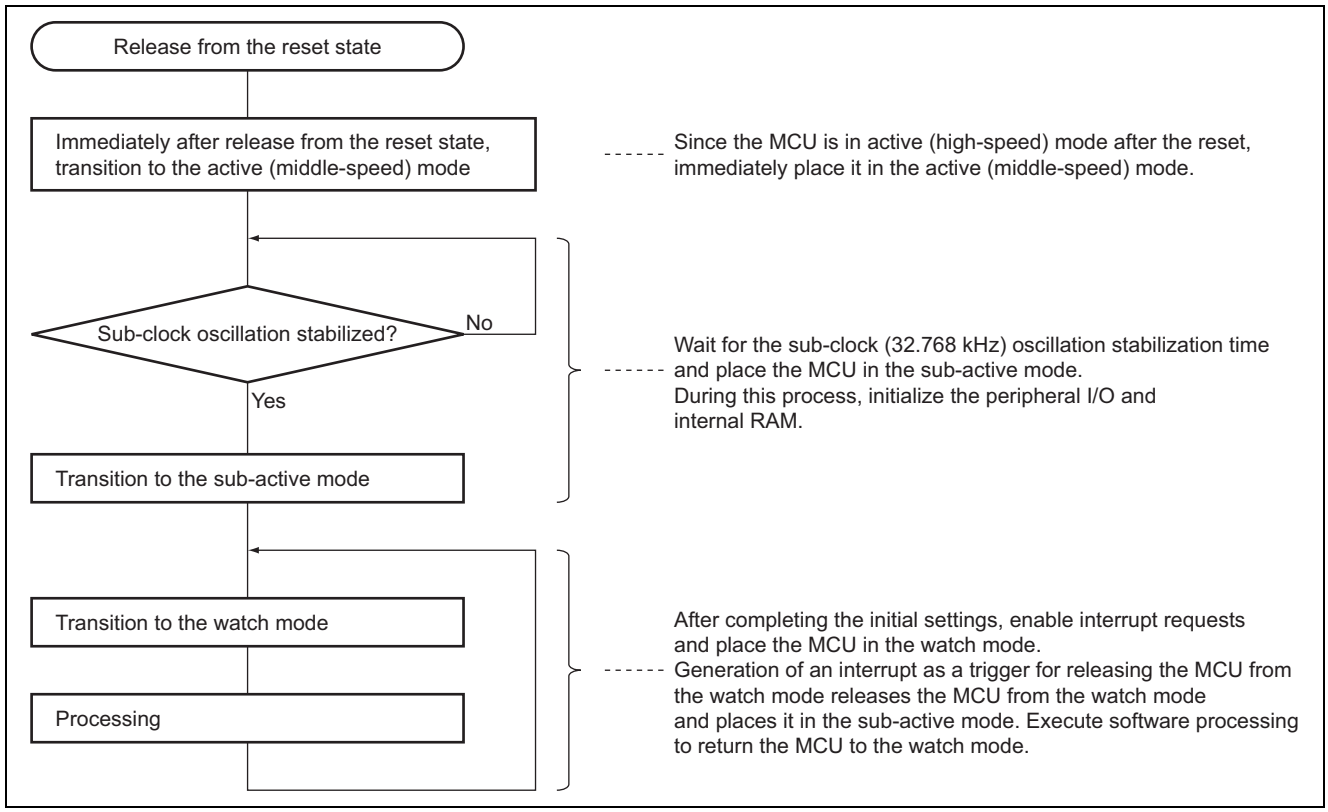
In order to operate the Super Low Power Series MCU, increasing output current of step-up DC/DC converter and reducing current drawn by the MCU is required.

To reduce the current drawn by the MCU, the following countermeasures can be considered.

- Reduce the number of operating power-supply voltage of the MCU
- Reduce the operating frequency for the MCU
- Use the on-chip oscillator for system clock (in case of product with on-chip oscillator for system clock)
- Switch the LSI circuit from the active (high-speed) mode to the active (middle-speed) mode after a reset. Switch it to the sub-active mode after stabilization of sub-clock oscillation.
- When the software does not operate, transit to the standby mode or watch mode.

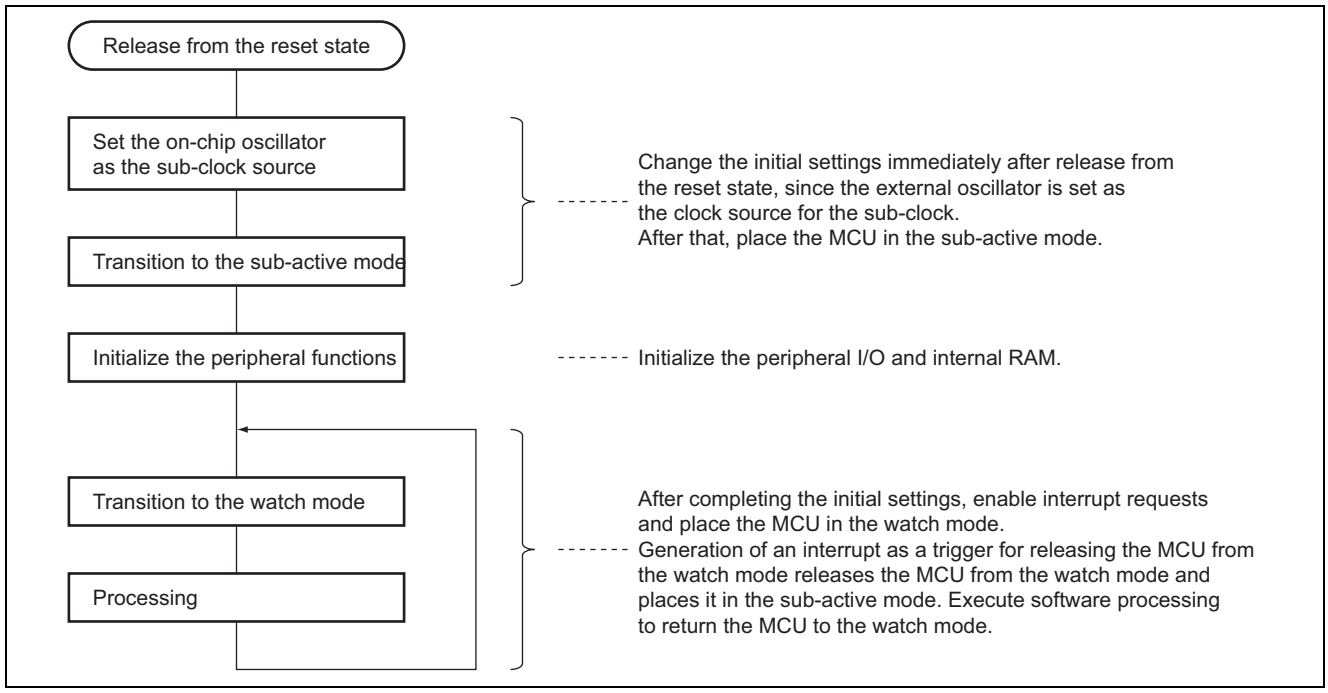
The following chart shows the transition from the active (high-speed) mode to the active (middle-speed) mode after a reset, the transition to the sub-active mode after the sub-clock oscillation is stabilized, and then the transition to the watch mode.

- Flow which minimizes the current drawn by general products of the Super Low Power Series



The products for which the on-chip oscillator can be used as the sub-clock enable the transition to the sub-active mode to be made without waiting for the oscillation of the external sub-clock to be stabilized.

- Flow which minimizes the current drawn by products for which the on-chip oscillator can be used as the sub-clock.



3. Reference Documents

1. Datasheet
   STEP-UP, PWM CONTORL or PWM/PFM SWITCHABLE BUILT-IN TRANSISTOR SWITCHING REGULATOR S-8353/8354 Series:
   Seiko Instruments Inc.

2. Datasheet
   ULTRA-LOW VOLTAGE OPERATON CHARGE PUMP IC FOR STEP-UP DC-DC CONVERTER STARTUP S-882Z Series:
   Seiko Instruments Inc.

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