RL78/I1A

IPD-less Digital Switching Power Circuit Using RL78/I1A

Introduction

This application note provides an example for achieving an IPD-less auxiliary power circuit using an AC/DC switching control IC RL78/I1A to reduce the cost of an AC/DC switching power circuit.

As an example, the following parts can be reduced by removing IPD from TPW-RL78I1A-2C.

	Increase/decrease in the number of parts after removing IPD from TPW-RL78I1A-2C
IC	One LYT0006D (Power Integrations) removed
Capacitor	4 capacitors removed
Diode	One diode removed
Inductor	One inductor removed
Resistor	3 resistors increased

Target Device

RL78/I1A

When applying the sample program covered in this application note to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

Contents

1. Introduction

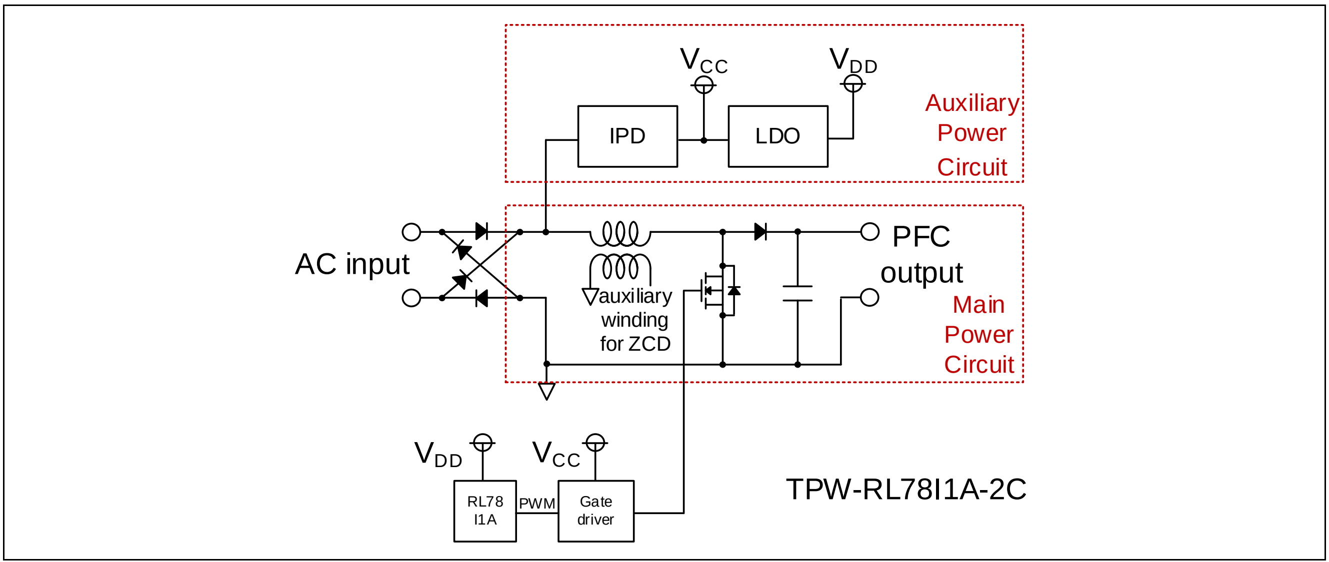
This application note provides an example of removing IPD from an LED power evaluation device (TPW-RL78I1A-2C) using RL78/I1A.

2. Overview of Circuit

2.1 Overall Circuit

A non-insulated step-up PFC control circuit is used in TPW-RL78I1A-2C. A gate driver power voltage (V_{CC}) is generated through IPD, and an MCU power voltage (V_{DD}) is generated through LDO from the main power circuit.

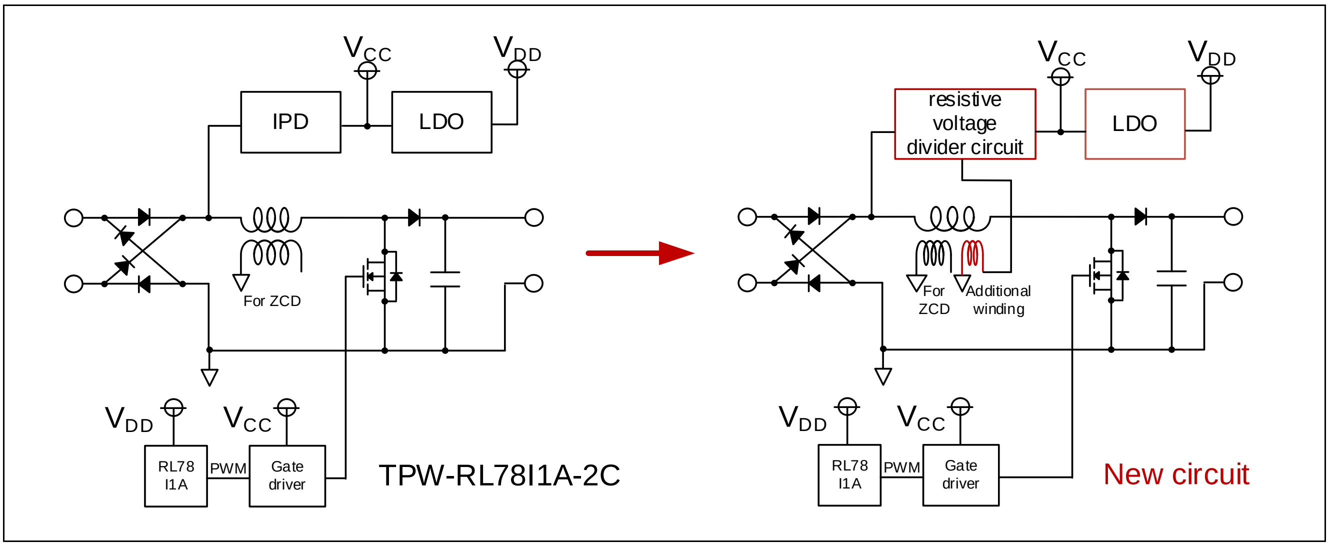
Figure 2 - 1 TPW-RL78I1A-2C Power Circuit Configuration



In this circuit, the IPD is replaced with a new circuit (consisting of a resistive voltage divider circuit and auxiliary winding) from TPW-RL78I1A-2C. In the new circuit, the AC input voltage after full-wave rectification goes through a resistive voltage divider circuit and is then smoothed by capacitors, generating an MCU power voltage through LDO. An auxiliary winding is added to the choke coil to supplement power from the auxiliary winding, in addition to the resistive voltage divider circuit, during PFC switching to minimize current flow in the resistive voltage divider circuit.

In TPW-RL78I1A-2C, an auxiliary winding for ZCD is provided for the choke coil. To simplify circuit design, however, another auxiliary winding is added in this circuit.

Figure 2 - 2 Auxiliary Power Circuit Configuration



Note: The ZCD auxiliary winding and additional auxiliary winding can be used as one winding depending on conditions.

3. Details of Circuit

3.1 Overall Configuration of Auxiliary Power Circuit

Figure 3 - 1 shows the overall configuration of the auxiliary power circuit.

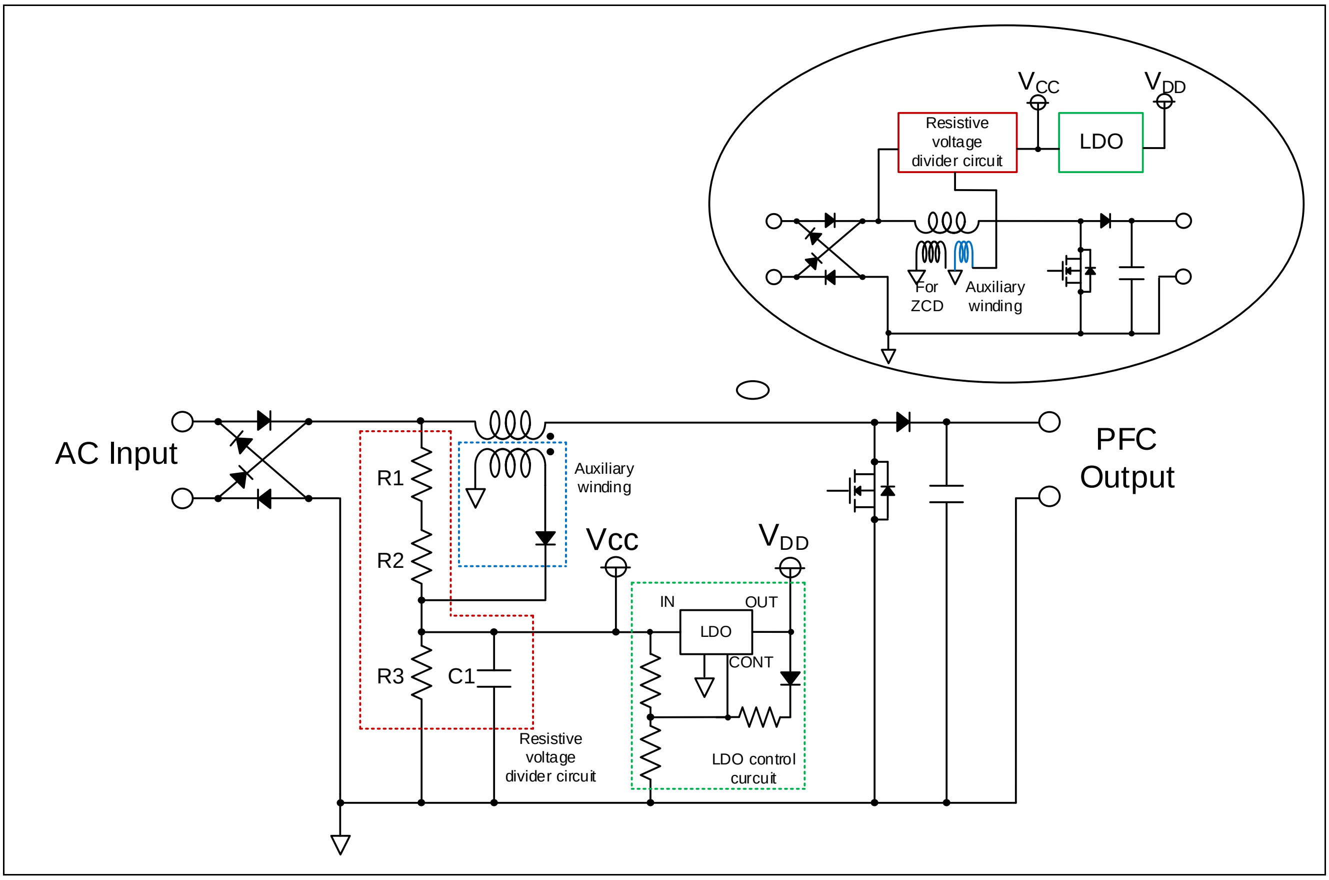
As shown in Figure 3 - 1, the new circuit mainly consists of a resistive voltage divider circuit, an LDO control circuit, and an auxiliary winding circuit. Details of each circuit are described in the following sections.

・Resistive voltage divider circuit: Section 3.1.1

・LDO control circuit: Section 3.1.2

・Auxiliary winding circuit: Section 3.1.3

Figure 3 - 1 Overall Configuration of Auxiliary Power Circuit



V_{CC} : Power supply for switching driver

V_{DD} : Power supply for MCU

Figure 3 - 2 shows the current route before and after activating the MCU.

As shown in the left circuit diagram in Figure 3 - 2, the MCU current is supplied from the resistive voltage divider circuit after power is turned on before the MCU is activated. After the MCU is activated and switching starts, the MCU current is supplied from the auxiliary winding of the choke coil.

Figure 3 - 2 Main MCU Power Supply Route

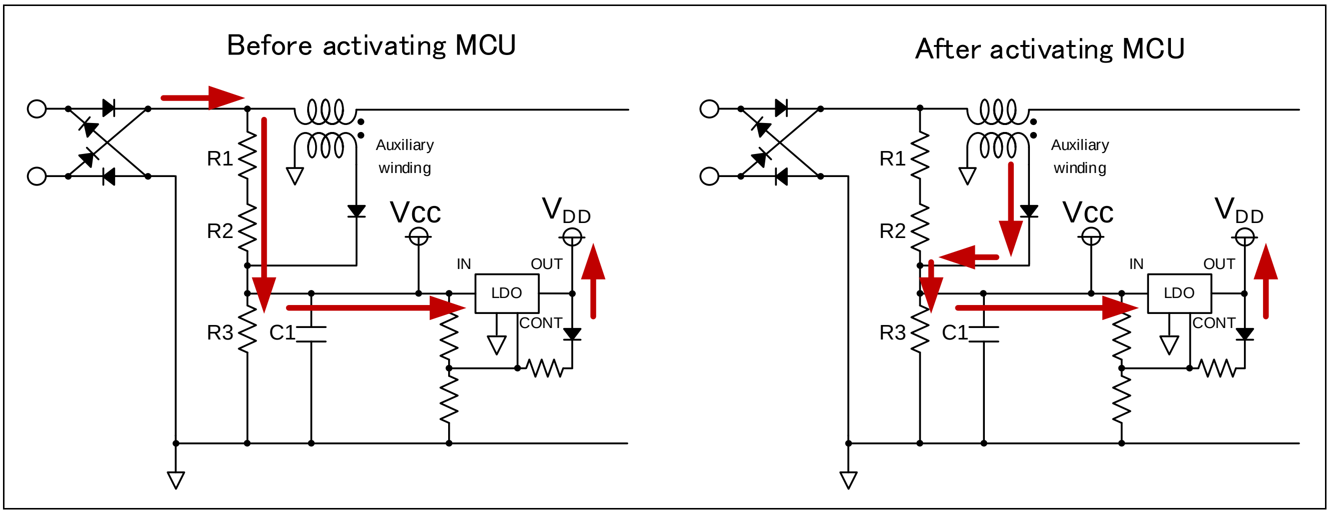
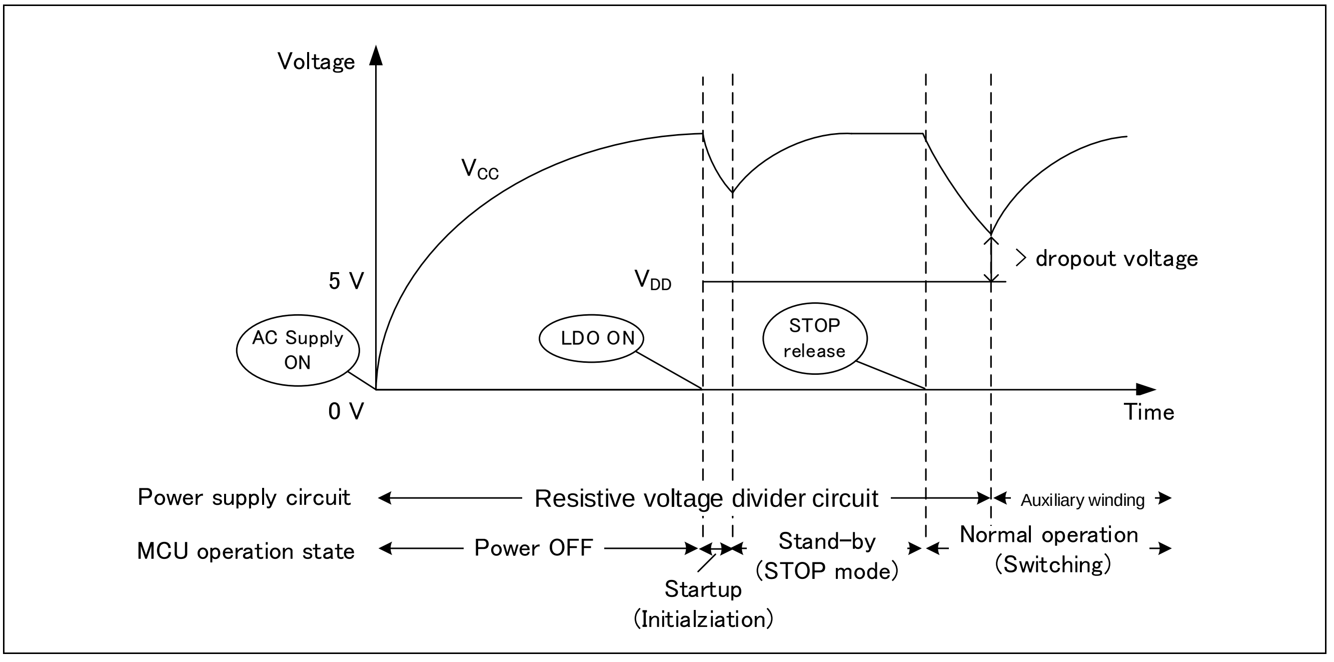


Figure 3 - 3 shows the waveforms of voltages V_{CC} and V_{DD} after AC power is turned on until switching starts. An RC circuit is provided before the LDO. After power is turned on, capacitor C1 is gradually charged. When capacitor C1 is fully charged, the LDO is activated by controlling its CONTROL pin signal. However, current required for high-speed operation in the MCU cannot be supplied only by the resistive voltage divider circuit. Therefore, C1 is gradually discharged after the LDO is activated.
For this reason, to prevent V_{CC} dropping below the specified voltage for input-output voltage of the LDO, the MCU enters standby mode (to reduce MCU current), or switches to supply current from the auxiliary winding to restore V_{CC}.
In Figure 3 - 3, the MCU is activated and enters standby mode. Then switching is started by the external input signal.

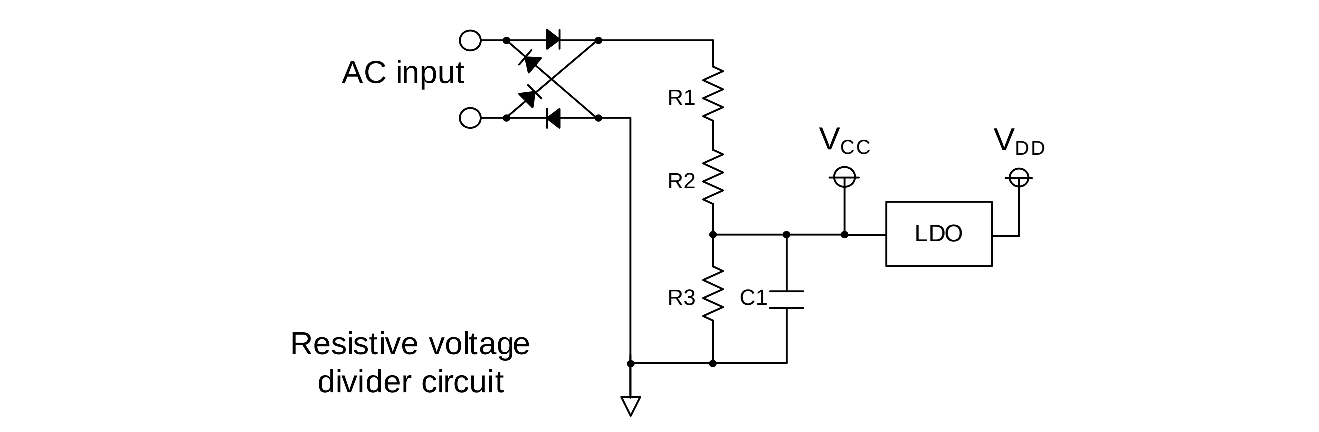
Figure 3 - 3 Waveforms of Voltages V_{CC} and V_{DD}



3.1.1 Resistive Voltage Divider Circuit

This circuit is used to activate the MCU when AC power is turned on. Figure 3 - 4 shows the circuit diagram.

Figure 3 - 4 resistive voltage divider circuit



V_{CC}: Pre-driver power voltage, V_{DD}: MCU power voltage (5 V)

In the resistive voltage divider circuit, the full-wave-rectified AC input voltage is divided by resistors R1, R2, and R3, and then smoothed by capacitor C1. The smoothed AC voltage is stepped down to 5 VDC by the LDO, and is then supplied to the MCU.

The resistive voltage divider circuit is designed to reduce the current to the minimum necessary to mitigate resistor power loss. For this reason, the current required for activating the MCU system (assuming 5 mA current required for 10 ms in this circuit) is supplied from the resistive voltage divider circuit and charged capacitor C1.

Table 3-1 lists conditions to be considered for designing resistance values (R1, R2, and R3) and capacitance value (C1). An example of designing R1, R2, R3, and C1 values to meet a worst case scenario is described in sections 3.1.2 and 3.1.3.

Table 3-1 Conditions to Be Considered for Determining Parameters (90 VAC – 260 VAC)

Related Parameters	Conditions to Be Considered	Worst Conditions
R1, R2, R3	・The VCC voltage is not less than the pre-driver operating voltage.	90 VAC
R1, R2, R3	・The VCC voltage meets the withstand voltages of connected elements. ・The loss in each resistor (including derating) meets the ratings.	260 VAC
R1, R2, R3, C1 LDO activation voltage	・Charges that can activate the MCU can be charged (depending on system). ・The startup time (C1 charging time at power-on) is within the allowable range.	90 VAC

3.1.1.1 Designing Resistance Values R1, R2, and R3

The V_{CC} voltage that is output from the resistive voltage divider circuit is determined from the AC input voltage and the resistance values R1, R2, and R3.

Assuming that the V_{CC} voltage is obtained by dividing the average AC voltage, V_{CC} can be calculated as follows. (The LDO circuit is not taken into consideration for simplification.)

$$Vav = \frac{2}{\pi} Vm = \frac{2}{\pi}\sqrt{2}\,Vrms$$

$$Vcc = \frac{R3}{R1 + R2 + R3} Vav$$

V_{av}: Average AC voltage, V_m: Maximum AC voltage, V_{rms}: Effective value of AC voltage

According to the conditions listed in Table 3-1, it should be considered that V_{CC} is not more than the maximum operating voltage (260 VAC) and is not less than the minimum operating voltage (90 VAC) of the pre-driver, and power at 260 VAC with resistance R1 to R3 is less than the rated value. (Thus, use values for R1, R2, and R3 that allow for steady current flow.)

The operating voltage of the pre-driver (IXYS602PI produced by IXYS Integrated Circuits Division) used in this circuit is 4.5 V to 35 V. Therefore, R1, R2 = 68 kΩ and R3 = 15 kΩ were set as a result of designed resistance values R1, R2, and R3 based on the conditions mentioned above.

Table 3-2 Estimated Values of AC Voltage, Resistances (R1, R2, and R3), and V_{CC} Voltage

AC (V)	Vav (V)	R1, R2 (kΩ)	R3 (kΩ)	V_{CC} (V)	R1, R2 Power (W)	R3 Power (W)
90	81.1	68	15	8.04	0.020	0.0023
260	234.1	68	15	23.25	0.163	0.0360

3.1.1.2 Capacitance C1

Assuming that 5 mA current is required for activating the MCU for 10 ms and the LDO is activated by a V_{CC} voltage of approximately 7 V, capacitance C1 is calculated based on the condition that the voltage drop in capacitor C1 is 1.5 V or less.

The quantity of electric charge Q and capacitance C of capacitor C1, voltage V, current *i*, and time *t* are in the following relationship.

$$Q = CV = it$$

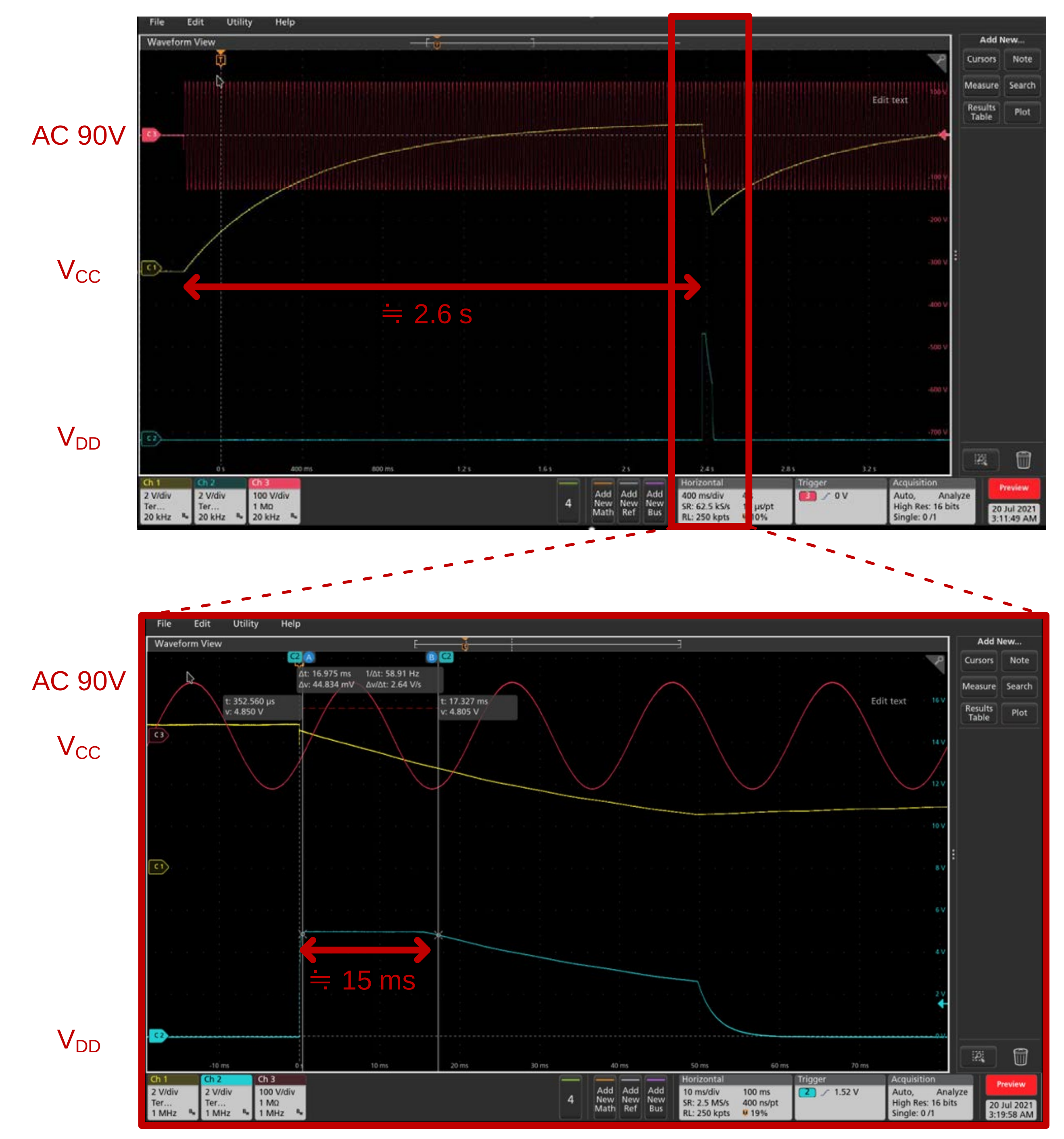
When the above conditions are assigned to this equation,

$$C = \frac{it}{V} = \frac{0.005 * 0.01}{1.5} = 33 * 10^{-6}$$

Thus, capacitance C is 33 μF.
Here, C1 capacitance is set to 47 μF with a margin.

Figure 3 - 5 shows the result of evaluation based on the above design using an actual device. At 90 VAC, where the current supply ability of the resistive voltage divider circuit is lowest, the interval from AC power on to LDO activation is approximately 2.6 s, and the VDD = 5 V hold time with a load of 5 mA connected is approximately 15 ms.

Figure 3 - 5 V_{CC}/V_{DD} Voltage Waveforms (R1, R2 = 68 kΩ, R3 = 15 kΩ, C1 = 47 μF, 5 mA Load Connected to V_{DD})



The result in Figure 3 - 5 verifies that the resistive voltage divider circuit can provide the current required to activate RL78/I1A (5 mA for 10 ms). However, high-speed operation in the MCU is not enabled only with the current supplied from the resistive voltage divider circuit.

For this reason, a circuit that supplies power from the auxiliary winding of a PFC transformer for constant power supply to the MCU is described in the following section.

3.1.2 LDO Operation Control

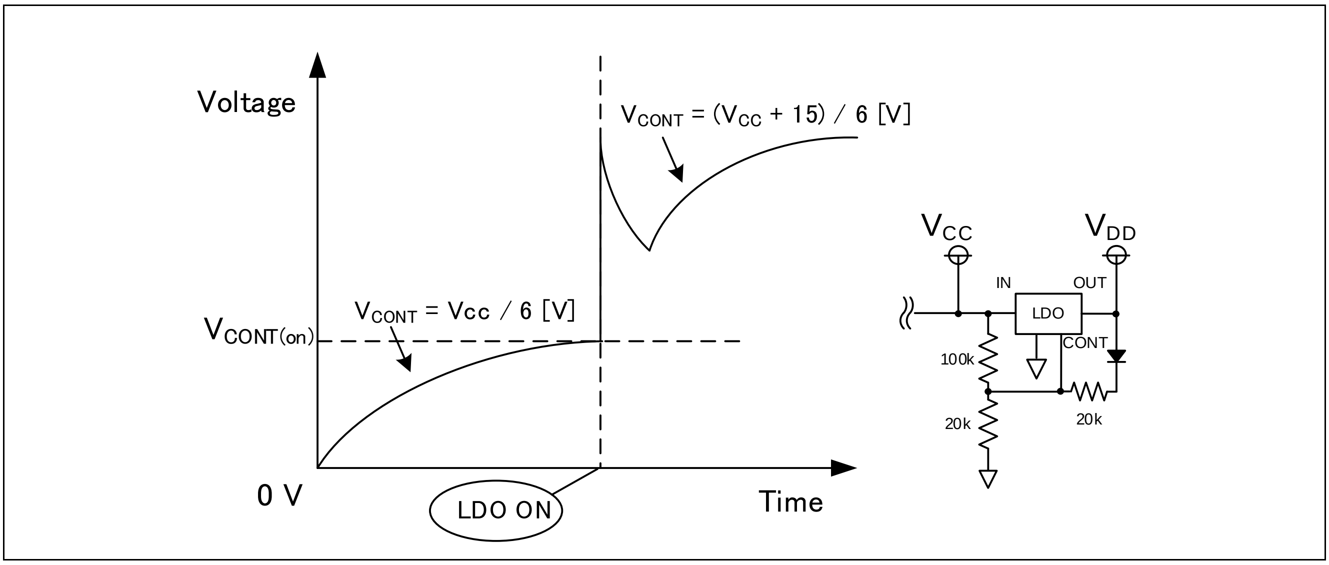
An LDO with an enable control (CONTROL) function is used in this circuit.

After AC power is turned on, capacitor C1 is gradually charged. After the V_{CC} voltage becomes constant, the CONTROL pin is controlled to activate the LDO.

The LDO (NJW4104U2-05B produced by Nissinbo Micro Devices Inc.) used in this circuit is activated when the CONTROL pin voltage ($V_{CONT(on)}$) is 1.2 V. For this reason, this circuit is designed to divide the V_{CC} voltage so that the LDO is activated at 7.2 V.

After the LDO is activated, the output voltage is input to the CONTROL pin to have hysteresis for continuous LDO operation even if V_{CC} drops.

Table 3-3 LDO Control Waveform



3.1.3 Power Supply Circuit Using PFC Transformer Auxiliary Winding

After the MCU is activated and switching starts, the auxiliary winding on the choke coil provides power by utilizing voltage fluctuations caused by switching.

Figure 3 - 7 shows the voltage waveform between both ends of the choke coil during switching. This voltage is divided by the turns ratio of the transformer, and the V_{CC} waveform is rectified by the diode and capacitor C1.

In TPW-RL78I1A-2C, an auxiliary winding on the choke coil detects the zero current signal. Therefore, a 6-turn winding is added to this auxiliary winding, forming a transformer (primary side: 106 turns, secondary side: 6 turns). The power supply circuit is designed to supply power from the added winding after PFC switching starts by connecting the transformer to the bottom end of resistor R2 in the resistive voltage divider circuit after rectification by the diode. When the turns ratio is 106:6, this circuit can generate a voltage of approximately 12 V (at 260 V) to 20 V (at 90 V). (Figure 3 - 8, Figure 3 - 9)

Determine the optimum turns ratio according to the circuit to be used so that the auxiliary winding output does not exceed the withstand voltage of each element.

Figure 3 - 6 Power Supply Circuit Using Auxiliary Winding

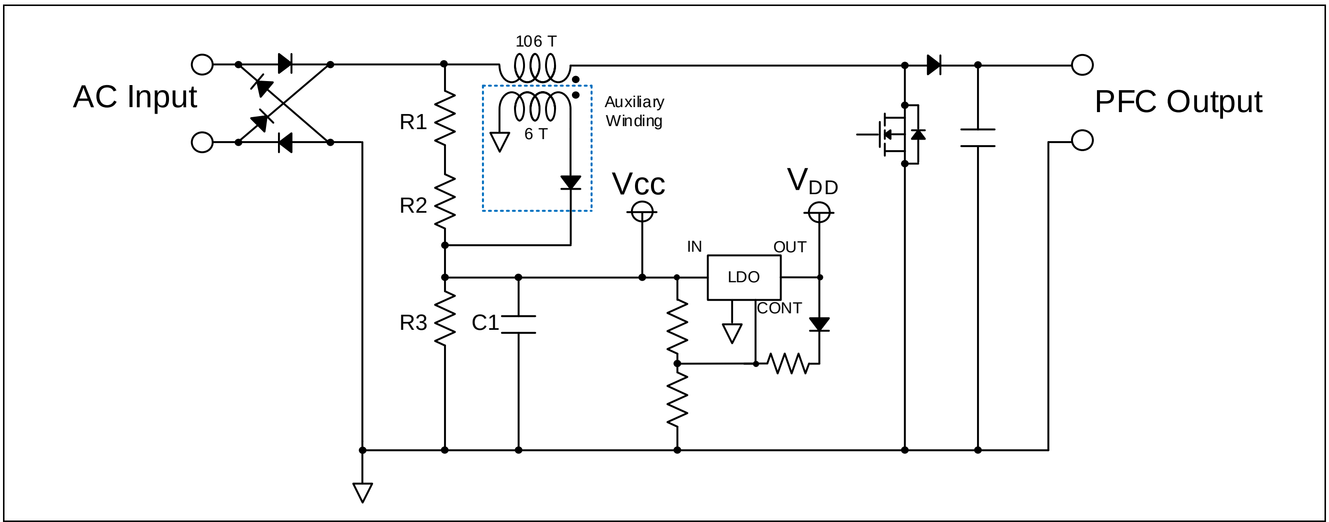


Figure 3 - 7 Voltage Waveform at Both Ends of Choke Coil in Steady State (Switching cycle and duty cycle differ from actual values)

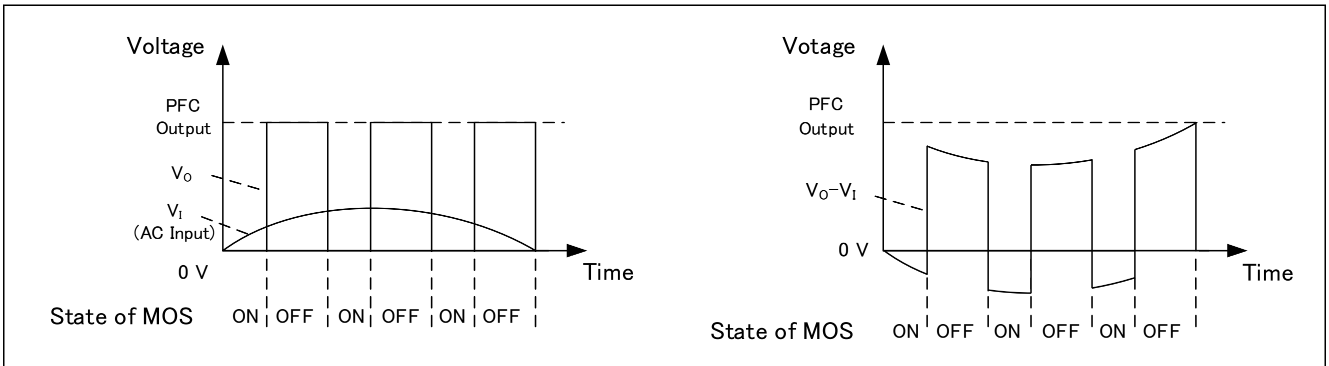


Figure 3 - 8 Auxiliary Winding Output Voltage (at 90 VAC, Upper Waveform: Auxiliary Winding Voltage, Lower Waveform: V_{CC})

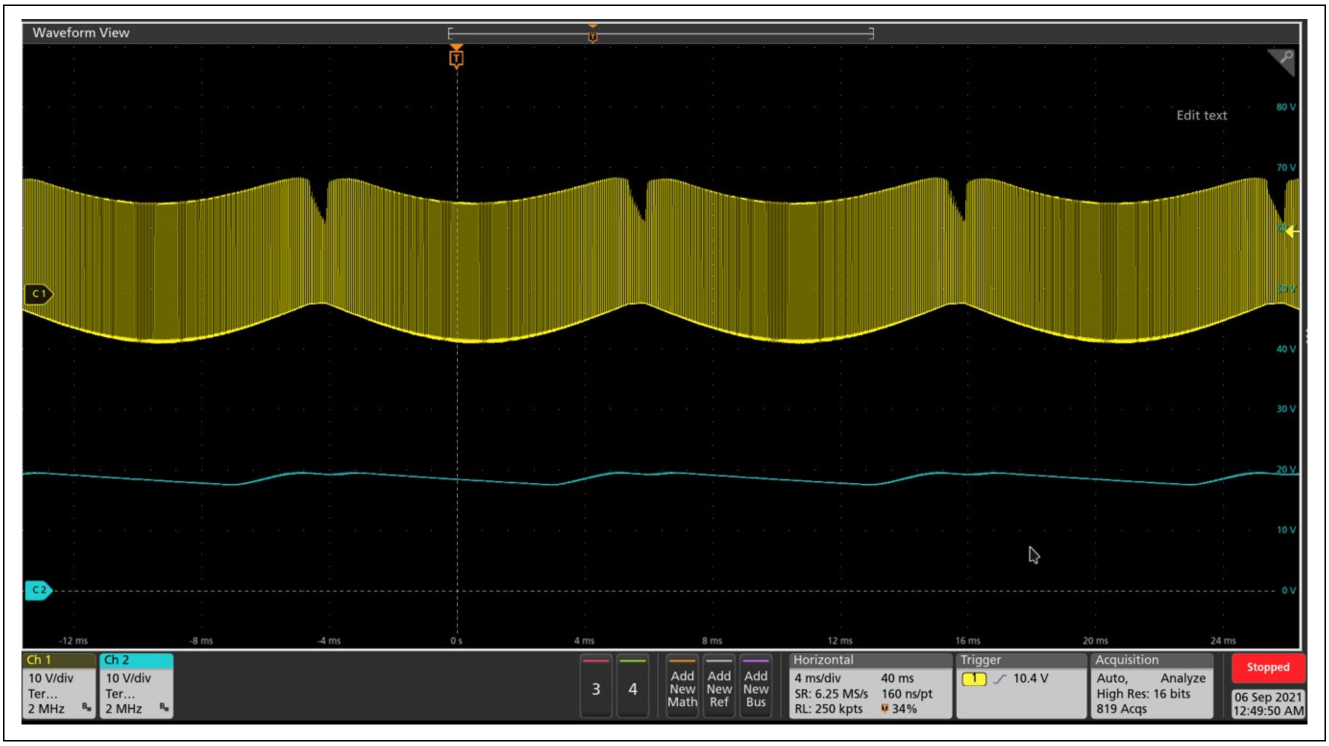


Figure 3 - 9 Auxiliary Winding Output Voltage (at 260 VAC, Upper Waveform: Auxiliary Winding Voltage, Lower Waveform: V_{CC})

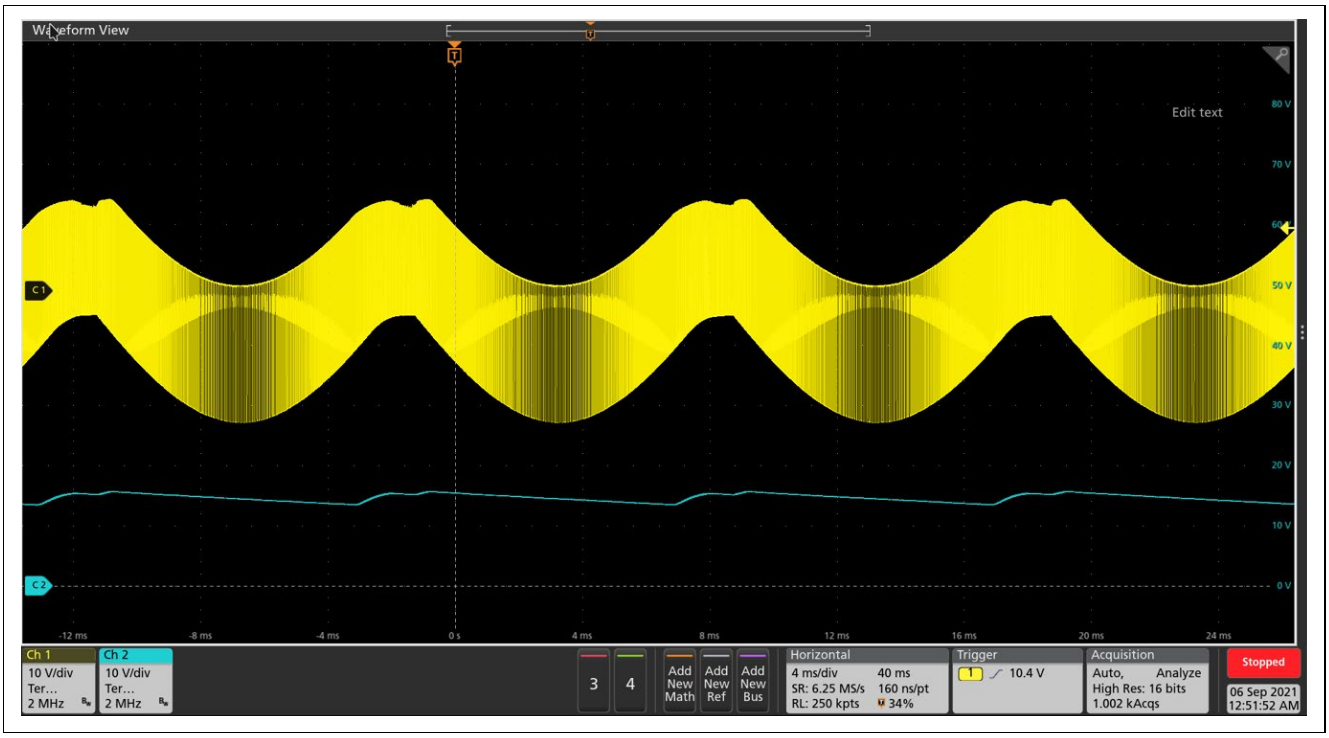


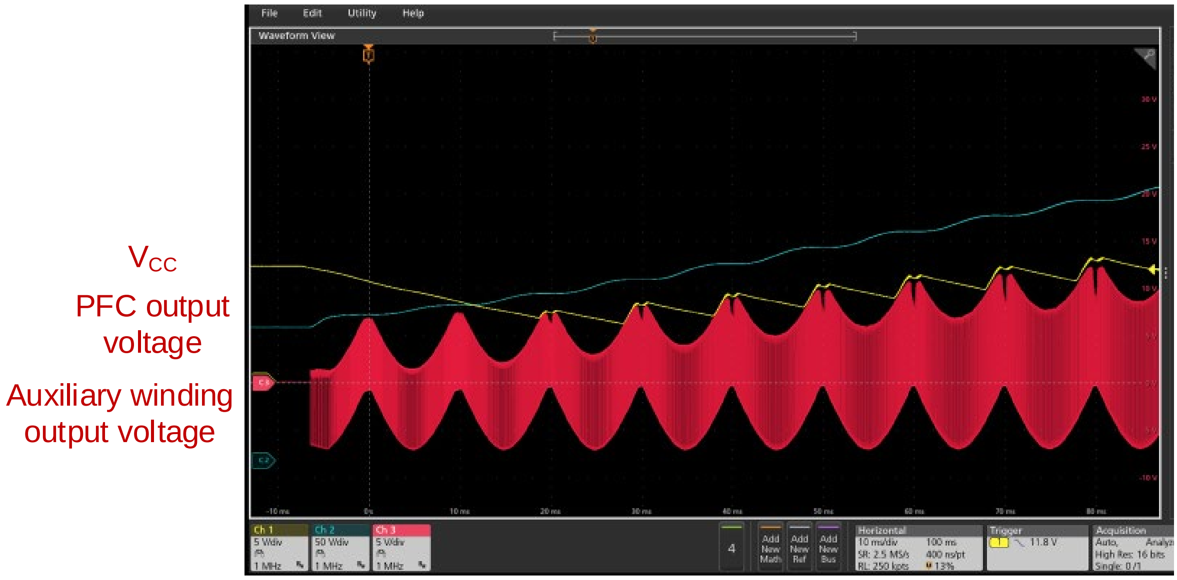
Figure 3 - 10 shows the V_{CC} waveform at the beginning of switching.

Because the PFC output voltage gradually rises after switching starts, the voltage difference between both ends of the choke coil is small immediately after switching starts at 90 VAC in particular, which prevents an output voltage higher than V_{CC} (supplied from the resistive voltage divider circuit) from being generated. After that, when the PFC output voltage rises and the auxiliary winding output voltage exceeds V_{CC}, current supply from the auxiliary winding starts.

In Figure 3 - 10, the auxiliary winding output voltage exceeds V_{CC} after 20 ms and current supply from the auxiliary winding starts.

If suppression of V_{CC} voltage drop is required, MCU current should be decreased.

Figure 3 - 10 Auxiliary Winding Output Voltage (at 90 VAC)



4. Example of Circuit Constant Design for Application

4.1 Design Example of Resistive Voltage Division Ratio and Capacitance (V_{DD} current = 15 mA)

In 3.1.1 Resistive Voltage Divider Circuit, a V_{DD} current of 5 mA is estimated. Table 4-1 shows a parameter design example when 15 mA V_{DD} current is required.

When mounting elements in an actual circuit or changing parameters, adequate evaluation is required to verify that the conditions listed in Table 3-1 are met.

Table 4-1 Parameter Design Example (V_{DD} Current = 15 mA)

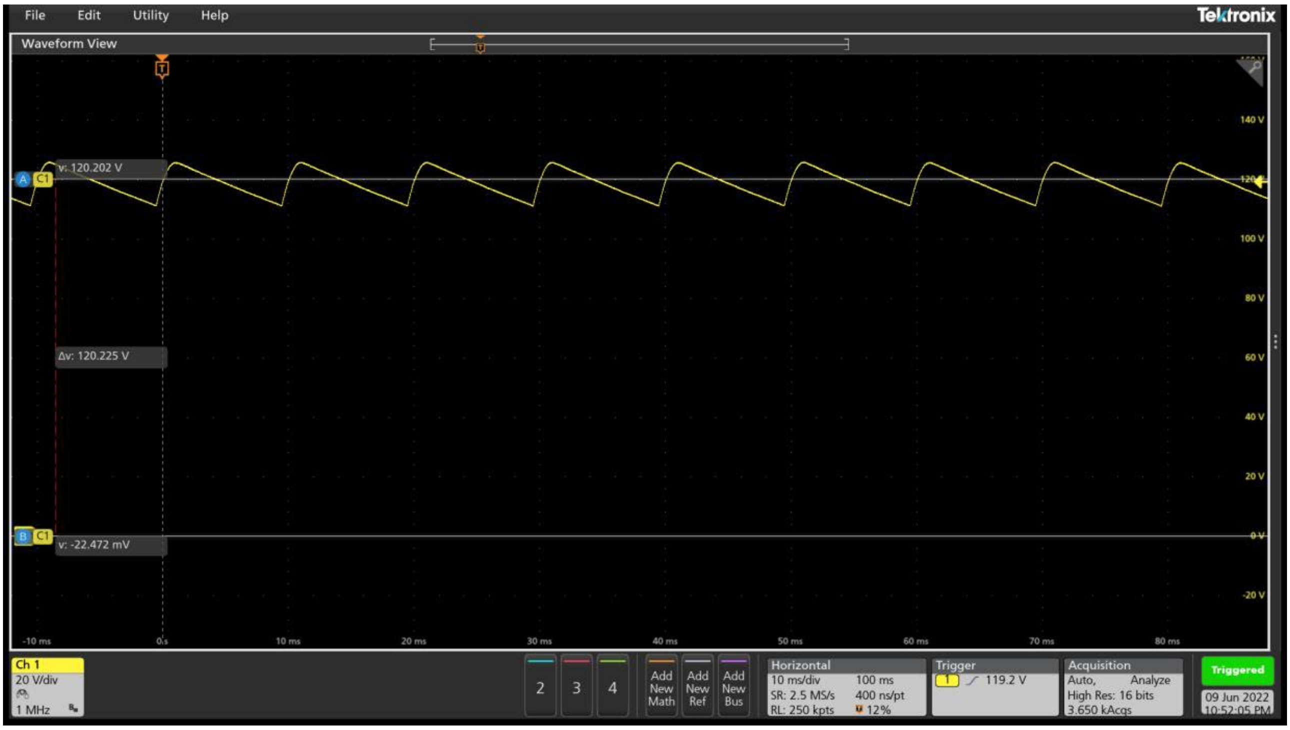
V_{DD} Current	R1, R2	R3	C1
5 mA	68 kΩ	15 kΩ	57 μF
15 mA	33 kΩ	8.2 kΩ	100 μF

4.2 Notes

4.2.1 V_{CC} Voltage Generated by Resistive Voltage Divider Circuit

In 3.1.1 Resistive Voltage Divider Circuit, it is assumed that the PFC circuit is not considered and V_{CC} is generated by dividing the average AC voltage. In the actual circuit (TPW-RL78I1A-2C), however, a rectification diode and a capacitor are connected (as a PFC circuit) after the rectification bridge circuit. Because the voltage shown in Figure 4 - 1 is input to the resistive voltage divider circuit before switching starts, V_{CC} is obtained by dividing approximately 120 VDC by resistors R1, R2, and R3 at 90 VAC.

Figure 4 - 1 Resistive Voltage Divider Circuit Input Voltage (at 90 VAC)



4.2.2 Considerations for Commercial Voltage Phase

The startup time at the beginning of switching varies with the phase of commercial power voltage. When using a commercial power supply in your system, evaluate the system adequately considering the phase of the commercial power voltage.

4.2.3 Selection of LDO

The input/output potential difference of the LDO affects the limit current at the beginning of switching. Select devices with a small input/output potential difference. In NJW4104U2-05B used in this circuit, the input/output phase difference is 0.25 V (Max.).

5. Reference Documents

RL78/I1A User’s Manual: Hardware (R01UH0169)
RL78 family user's manual software (R01US0015)
The latest versions can be downloaded from the Renesas Electronics website.

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

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Revision History

Rev.	Date	Description	
		Page	Summary
1.00	2022.12.27	—	First Edition

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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.
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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.).
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