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# XC9501 Series

# 2ch. Step-up DC/DC Controller ICs.

Mar. 17, 2003 Ver. 5

- 2ch DC/DC Controller (Step-up + Step-up)
- Input Voltage Range 0.9V ~ 10.0V
- Output Voltage Externally Set-Up
- Switching Frequency 180kHz (±15%)
- Max Duty Ratio 80% (TYP.)
- PWM, PWM/PFM Switching Control
- High Efficiency 83% (TYP.)
- MSOP-10 Package

## ■ Applications

- PDAs
- Palm top computers
- Portable Audio Systems
- Various Multi-function Power Supplies

## ■ Features

| | |
|---|---|
| **Input Voltage Range** | :0.9V ~ 10V |
| **Power Supply Voltage Range** | :2.0V ~ 10V |
| **Output Voltage Range** | :1.5V ~ 30V<br>Can be set freely with 0.9V(± 2.0%) of reference voltage supply & external components. |
| **Switching Frequency** | :180kHz ±15%<br>:300kHz & 500kHz available as custom |
| **Output Current** | :more than 200mA(VIN=1.8V, VOUT=3.3V) |
| **Stand-by Current** | :3.0μA (MAX) |
| **Soft-start internally set-up** | |
| **MSOP-10 Package** | |

## ■ General Description

The XC9501 series are PWM controlled, PWM/PFM automatic switching controlled, multi-functional, dual step-up DC/DC converter controller ICs.
With 0.9V (±2%) of standard voltage supply internal, and using externally connected components, output voltage can be set freely on both DC/DC controllers between 1.5V to 30V.
With a 180kHz frequency, the size of the external components can be reduced. 300kHz and 500kHz switching frequencies are also available as custom-designed products.
The control of the XC9501 series can be switched between PWM control and PWM/PFM automatic switching control using external signals. Control switches from PWM to PFM during light loads when automatic switching is selected and the series is highly efficient from light loads to large output currents.
Noise is easily reduced with PWM control since the switching frequency is fixed.
The XC9501 series provides the option of being able to select the control suited to the application.

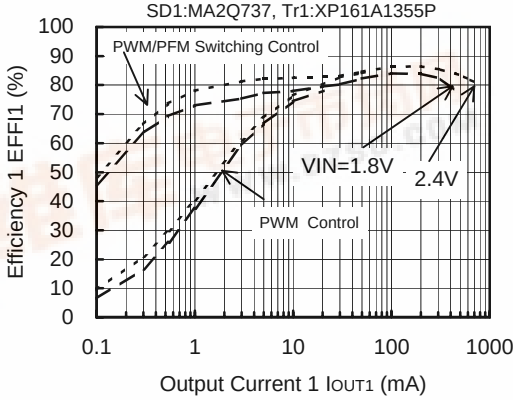
Soft-start time is internally set to 10msec which offers protection against rush currents when the power is switched on and also against voltage overshoot.

## ■ Typical Performance Characteristics

Efficiency vs. Output Current

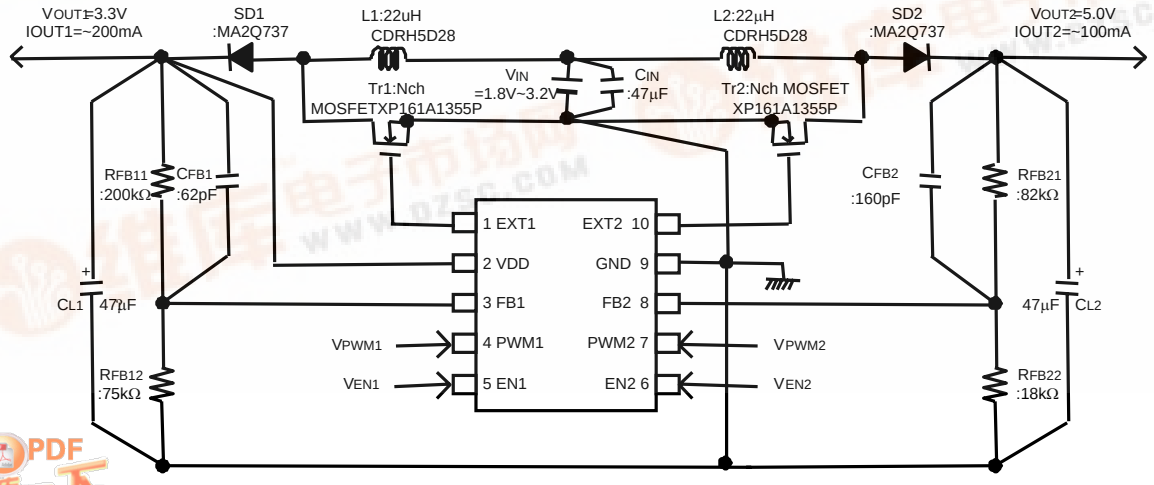
**XC9501B092A (180kHz,3.3V)**

L1=22μH(CDRH5D28), CL1=47μF(Tantalum)
SD1:MA2Q737, Tr1:XP161A1355P




## ■ Typical Application

( XC9501B092A Input: 2 cells, Output ①: 3.3V, Output ②: 5.0V )

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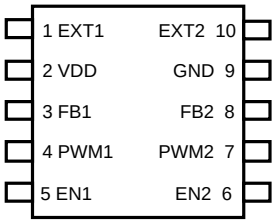
## ■ Pin Configuration




MSOP-10
(TOP VIEW)

## ■ Pin Assignment

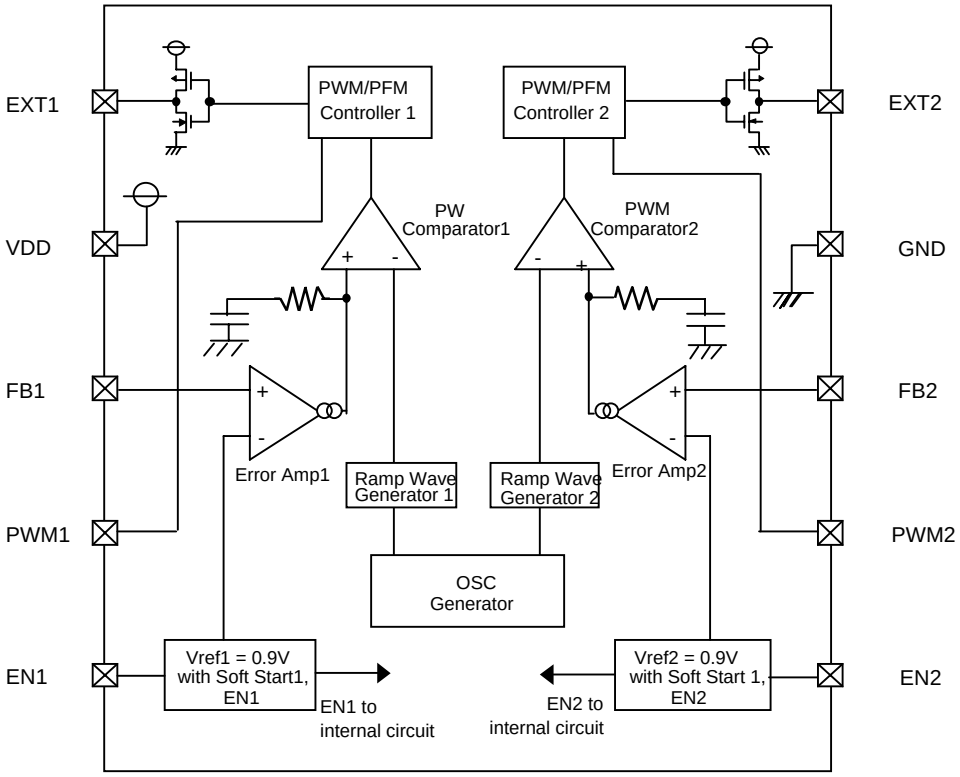
| PIN NUMBER | PIN NAME | FUNCTIONS |
|---|---|---|
| 1 | EXT 1 | Channel 1: External Transistor Drive Pin <Connected to Nch Power MOSFET Gate> |
| 2 | VDD | Supply Voltage |
| 3 | FB1 | Channel 1 : Output Voltage Monitor Feedback Pin <Threshold value : 0.9V. Output voltage can be set freely by connecting split resistors between VOUT1 and Ground.> |
| 4 | PWM1 | Channel 1 : PWM/PFM Switching Pin <Control Output 1. PWM control when connected to VDD, PWM / PFM auto switching when connected to Ground. > |
| 5 | EN1 | Channel 1 : Enable Pin <Connected to VDD when Output 1 is in stand-by mode. Connected to VDD when Output 1 is active. EXT1 is low when in stand-by mode.> |
| 6 | EN2 | Channel 2 : Enable Pin <Connected to Ground when Output 2 is in stand-by mode. Connected to VDD when Output 2 is active.EXT1 is high when in stand-by mode.> |
| 7 | PWM2 | Channel 2 : PWM/PFM Switching Pin <Control Output 2. PWM control when connected to VDD, PWM / PFM auto switching when connected to Ground.> |
| 8 | FB2 | Channel 2 : Output Voltage Monitor Feedback Pin <Threshold value : 0.9V. Output voltage can be set freely by connecting split resistors between VOUT2 and Ground.> |
| 9 | GND | Ground |
| 10 | EXT 2 | Channel 2 : External Transistor Drive Pin <Connected to Nch Power MOSFET Gate> |

## ■ Ordering Information

XC9501①②③④⑤⑥

| DESIGNATOR | SYMBOL | DESCRIPTION | |
|---|---|---|---|
| ① | B | Standard (10 Pin) | |
| ② | 0 | FB Voltage | |
| ③ | 9 | 0.9V | |
| ④ | | Switching Frequency | |
| | 2 | 180kHz | |
| | 3 | 300kHz (custom) | |
| | 5 | 500kHz (custom) | |
| ⑤ | A | Package | MSOP-10 |
| ⑥ | R | Embossed Tape | Standard Feed |
| | L | Embossed Tape | Reverse Feed |

## ■ Block Diagram




## ■ Absolute Maximum Ratings

Ta=25°C

| PARAMETER | SYMBOL | RATINGS | UNITS |
|---|---|---|---|
| VDD Pin Voltage | VDD | - 0.3 ~ 12 | V |
| FB1, 2 Pin Voltage | VFB | - 0.3 ~ 12 | V |
| EN1, 2 Pin Voltage | VEN | - 0.3 ~ 12 | V |
| PWM1,2 Pin Voltage | VPWM | - 0.3 ~ 12 | V |
| EXT1, 2 Pin Voltage | VEXT | - 0.3 ~ VDD + 0.3 | V |
| EXT1, 2 Pin Current | IEXT | ± 100 | mA |
| Power Dissipation | Pd | 150 | mW |
| Operating Ambient Temperature | Topr | - 40 ~ + 85 | °C |
| Storage Temperature | Tstg | - 55 ~ + 125 | °C |

## ■ Electrical Characteristics XC9501B092A

**Common Characteristics** (FOSC=180kHz) Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | | MIN. | TYP. | MAX. | UNITS | TEST CIRCUIT |
|---|---|---|---|---|---|---|---|---|
| Supply Voltage (note 1) | VDD | | | 2.0 | - | 10.0 | V | |
| Output Voltage Range (note 4) | VOUTSET | VDD ≥ 2.0V, IOUT1, 2 =1mA | VOUT1, VOUT2 | 0.9 | - | - | V | ① |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 2) | VOUT1 | 2.0 | - | 10.0 | V | ② |
| | | | VOUT2 | 0.9 | - | - | V | |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 3) | VOUT1 | 0.9 | - | - | V | ③ |
| | | | VOUT2 | 2.0 | - | 10.0 | V | |
| Supply Current 1 | IDD1 | FB1,2=0V | | - | 90 | 160 | μA | ④ |
| Supply Current 1-1 | IDD1-1 | EN1=3.0V, EN2=0V, FB1=0V | | - | 60 | 120 | μA | ④ |
| | | EN2=3.0V, EN1=0V, FB2=0V | | | | | | |
| Supply Current 1-2 | IDD1-2 | FB1=0V, FB2=1.0V | | - | 80 | 150 | μA | ④ |
| | | FB1=1.0V, FB2=0V | | | | | | |
| Supply Current 2 | IDD2 | FB1,2=1.0V | | - | 70 | 132 | μA | ④ |
| Stand-by Current | ISTB | Same as IDD1, EN1=EN2=0V | | - | - | 3.0 | μA | ④ |
| Switching Frequency | FOSC | Same as IDD1 | | 153 | 180 | 207 | kHz | ④ |
| EN1,2 "High" Voltage | VENH | FB1,2=0V | | 0.65 | - | - | V | ④ |
| EN1,2 "Low" Voltage | VENL | FB1,2=0V | | - | - | 0.20 | V | ④ |
| EN1,2 "High" Current | IENH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| EN1,2 "Low" Current | IENL | EN1,2=0V, FB1,2=3.0V | | - | - | -0.50 | μA | ④ |
| PWM1,2 "High" Current | IPWMH | FB1,2=3.0V, PWM=3.0V | | - | - | 0.50 | μA | ④ |
| PWM1,2 "Low" Current | IPWML | FB1,2=3.0V,PWM=0V | | - | - | -0.50 | μA | ④ |
| FB1,2 "High" Current | IFBH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| FB1,2 "Low" Current | VFBL | FB1,2=1V | | - | - | -0.50 | μA | ④ |

Unless otherwise stated, VDD=3.0V, PWM1,2=3.0V, EN1, 2 =3.0V

**Output 1 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | TEST CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB1 Voltage | VFB1 | VDD=3.0V, VIN=1.5V, IOUT1=10mA | 0.882 | 0.900 | 0.918 | V | ⑤ |
| Operation Start-up Voltage1 (note 2) | VST1-1 | Using Tr: 2SD1628, IOUT=1.0mA, RFB11=200kΩ, RFB12=75kΩ | - | - | 0.9 | V | ② |
| | | VDD ≠ VOUT1: IOUT1=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage1 | VST2-1 | FB1=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio1 | MAXDTY1 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio1 | PFMDTY1 | No Load, VPWM1=0V | 22 | 30 | 38 | % | ⑥ |
| Efficiency1 | EFFI1 | IOUT1=100mA Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑥ |
| Soft-Start Time1 | TSS1 | VOUT1 × 0.95V, CE1=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑥ |
| EXT1 "High" ON Resistance | REXTBH1 | FB1=0, EXT1=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT1 "Low" ON Resistance | REXTBL1 | EN1=FB2=0V, EXT1=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM1 "High" Voltage | VPWMH1 | No Load | 0.65 | - | - | V | ⑥ |
| PWM1 "Low" Voltage | VPWML1 | No Load | - | - | 0.20 | V | ⑥ |

Unless otherwise stated, VDD=EN1=PWM1=3.0V, EN2=PWM2=GND, EXT2=OPEN, FB2=OPEN, VIN=1.8V

**Output 2 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | TEST CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB2 Voltage | VFB2 | VDD=3.0V, VIN=1.5V, IOUT2=10mA | 0.882 | 0.900 | 0.918 | V | ⑧ |
| Operation Start-up Voltage2 (note 3) | VST1-2 | Using Tr: 2SD1628, IOUT2=1.0mA, RFB21=200kΩ,RFB22=75kΩ | - | - | 0.9 | V | ③ |
| | | VDD ≠ VOUT2 : IOUT2=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage2 | VST2-2 | FB2=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio2 | MAXDTY2 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio2 | PFMDTY2 | No Load, VPWM2=0V | 22 | 25 | 38 | % | ⑨ |
| Efficiency2 | EFFI2 | IOUT2=100mA, Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑨ |
| Soft-Start Time2 | TSS2 | VOUT2 × 0.95V, EN2=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑨ |
| EXT2 "High" ON Resistance | REXTBH2 | FB2=0, EXT2=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT2 "Low" ON Resistance | REXTBL2 | EN2=FB2=0V, EXT2=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM2 "High" Voltage | VPWMH2 | No Load | 0.65 | - | - | V | ⑨ |
| PWM2 "Low" Voltage | VPWML2 | No Load | - | - | 0.20 | V | ⑨ |

Unless otherwise stated, VDD=EN2=PWM2=3.0V, PWM1=EN1=GND, EXT1=OPEN, FB1=OPEN, VIN=1.8V

## ■ Electrical Characteristics XC9501B093A

**Common Characteristics** (FOSC=300kHz) Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|---|
| Supply Voltage (note 1) | VDD | | | 2.0 | - | 10.0 | V | |
| Output Voltage Range (note 4) | VOUTSET | VDD ≥ 2.0V, IOUT1, 2 =1mA | VOUT1, VOUT2 | 0.9 | - | - | V | ① |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 2) | VOUT1 | 2.0 | - | 10.0 | V | ② |
| | | | VOUT2 | 0.9 | - | - | V | |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 3) | VOUT1 | 0.9 | - | - | V | ③ |
| | | | VOUT2 | 2.0 | - | 10.0 | V | |
| Supply Current 1 | IDD1 | FB1,2=0V | | - | 110 | 250 | μA | ④ |
| Supply Current 1-1 | IDD1-1 | EN1=3.0V, EN2=0V, FB1=0V | | - | 80 | 150 | μA | ④ |
| | | EN2=3.0V, EN1=0V, FB2=0V | | | | | | |
| Supply Current 1-2 | IDD1-2 | FB1=0V, FB2=1.0V | | - | 90 | 200 | μA | ④ |
| | | FB1=1.0V, FB2=0V | | | | | | |
| Supply Current 2 | IDD2 | FB1,2=1.0V | | - | 80 | 160 | μA | ④ |
| Stand-by Current | ISTB | Same as IDD1, EN1=EN2=0V | | - | - | 3.0 | μA | ④ |
| Switching Frequency | FOSC | Same as IDD1 | | 255 | 300 | 345 | kHz | ④ |
| EN1,2 "High" Voltage | VENH | FB1,2=0V | | 0.65 | - | - | V | ④ |
| EN1,2 "Low" Voltage | VENL | FB1,2=0V | | - | - | 0.20 | V | ④ |
| EN1,2 "High" Current | IENH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| EN1,2 "Low" Current | IENL | EN1,2=0V, FB1,2=3.0V | | - | - | -0.50 | μA | ④ |
| PWM1,2 "High" Current | IPWMH | FB1,2=3.0V, PWM=3.0V | | - | - | 0.50 | μA | ④ |
| PWM1,2 "Low" Current | IPWML | FB1,2=3.0V,PWM=0V | | - | - | -0.50 | μA | ④ |
| FB1,2 "High" Current | IFBH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| FB1,2 "Low" Current | VFBL | FB1,2=1V | | - | - | -0.50 | μA | ④ |

Unless otherwise stated, VDD=3.0V, PWM1,2=3.0V, EN1, 2 =3.0V

**Output 1 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB1 Voltage | VFB1 | VDD=3.0V, VIN=1.5V, IOUT1=10mA | 0.882 | 0.900 | 0.918 | V | ⑤ |
| Operation Start-up Voltage1 (note 2) | VST1-1 | Using Tr: 2SD1628, IOUT=1.0mA, RFB11=200kΩ, RFB12=75kΩ | - | - | 0.9 | V | ② |
| | | VDD ≠ VOUT1: IOUT1=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage1 | VST2-1 | FB1=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio1 | MAXDTY1 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio1 | PFMDTY1 | No Load, VPWM1=0V | 22 | 30 | 38 | % | ⑥ |
| Efficiency1 | EFFI1 | IOUT1=100mA, Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑥ |
| Soft-Start Time1 | TSS1 | VOUT1 × 0.95V, CE1=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑥ |
| EXT1 "High" ON Resistance | REXTBH1 | FB1=0, EXT1=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT1 "Low" ON Resistance | REXTBL1 | EN1=FB2=0V, EXT1=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM1 "High" Voltage | VPWMH1 | No Load | 0.65 | - | - | V | ⑥ |
| PWM1 "Low" Voltage | VPWML1 | No Load | - | - | 0.20 | V | ⑥ |

Unless otherwise stated, VDD=EN1=PWM1=3.0V, EN2=PWM2=GND, EXT2=OPEN, FB2=OPEN, VIN=1.8V

**Output 2 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB2 Voltage | VFB2 | VDD=3.0V, VIN=1.5V, IOUT2=10mA | 0.882 | 0.900 | 0.918 | V | ⑧ |
| Operation Start-up Voltage2 (note 3) | VST1-2 | Using Tr: 2SD1628, IOUT2=1.0mA, RFB21=200kΩ,RFB22=75kΩ | - | - | 0.9 | V | ③ |
| | | VDD ≠ VOUT2 : IOUT2=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage2 | VST2-2 | FB2=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio2 | MAXDTY2 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio2 | PFMDTY2 | No Load, VPWM2=0V | 22 | 30 | 38 | % | ⑨ |
| Efficiency2 | EFFI2 | IOUT2=100mA, Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑨ |
| Soft-Start Time2 | TSS2 | VOUT2 × 0.95V, EN2=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑨ |
| EXT2 "High" ON Resistance | REXTBH2 | FB2=0, EXT2=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT2 "Low" ON Resistance | REXTBL2 | EN2=FB2=0V, EXT2=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM2 "High" Voltage | VPWMH2 | No Load | 0.65 | - | - | V | ⑨ |
| PWM2 "Low" Voltage | VPWML2 | No Load | - | - | 0.20 | V | ⑨ |

Unless otherwise stated, VDD=EN2=PWM2=3.0V, PWM1=EN1=GND, EXT1=OPEN, FB1=OPEN, VIN=1.8V

## ■ Electrical Characteristics XC9501B095A

**Common Characteristics** (FOSC=500kHz) Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|---|
| Supply Voltage (note 1) | VDD | | | 2.0 | - | 10.0 | V | |
| Output Voltage Range (note 4) | VOUTSET | VDD ≥ 2.0V, IOUT1, 2 =1mA | VOUT1, VOUT2 | 0.9 | - | - | V | ① |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 2) | VOUT1 | 2.0 | - | 10.0 | V | ② |
| | | | VOUT2 | 0.9 | - | - | V | |
| | | VIN ≥ 0.9V, IOUT1, 2=1mA (note 3) | VOUT1 | 0.9 | - | - | V | ③ |
| | | | VOUT2 | 2.0 | - | 10.0 | V | |
| Supply Current 1 | IDD1 | FB1,2=0V | | - | 165 | 350 | μA | ④ |
| Supply Current 1-1 | IDD1-1 | EN1=3.0V, EN2=0V, FB1=0V | | - | 110 | 220 | μA | ④ |
| | | EN2=3.0V, EN1=0V, FB2=0V | | | | | | |
| Supply Current 1-2 | IDD1-2 | FB1=0V, FB2=1.0V | | - | 130 | 270 | μA | ④ |
| | | FB1=1.0V, FB2=0V | | | | | | |
| Supply Current 2 | IDD2 | FB1,2=1.0V | | - | 100 | 200 | μA | ④ |
| Stand-by Current | ISTB | Same as IDD1, EN1=EN2=0V | | - | - | 3.0 | μA | ④ |
| Switching Frequency | FOSC | Same as IDD1 | | 425 | 500 | 575 | kHz | ④ |
| EN1,2 "High" Voltage | VENH | FB1,2=0V | | 0.65 | - | - | V | ④ |
| EN1,2 "Low" Voltage | VENL | FB1,2=0V | | - | - | 0.20 | V | ④ |
| EN1,2 "High" Current | IENH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| EN1,2 "Low" Current | IENL | EN1,2=0V, FB1,2=3.0V | | - | - | -0.50 | μA | ④ |
| PWM1,2 "High" Current | IPWMH | FB1,2=3.0V, PWM=3.0V | | - | - | 0.50 | μA | ④ |
| PWM1,2 "Low" Current | IPWML | FB1,2=3.0V,PWM=0V | | - | - | -0.50 | μA | ④ |
| FB1,2 "High" Current | IFBH | FB1,2=3.0V | | - | - | 0.50 | μA | ④ |
| FB1,2 "Low" Current | VFBL | FB1,2=1V | | - | - | -0.50 | μA | ④ |

Unless otherwise stated, VDD=3.0V, PWM1,2=3.0V, EN1, 2 =3.0V

**Output 1 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB1 Voltage | VFB1 | VDD=3.0V, VIN=1.5V, IOUT1=10mA | 0.882 | 0.900 | 0.918 | V | ⑤ |
| Operation Start-up Voltage1 (note 2) | VST1-1 | Using Tr: 2SD1628, IOUT=1.0mA, RFB11=200kΩ, RFB12=75kΩ | - | - | 0.9 | V | ② |
| | | VDD ≠ VOUT1: IOUT1=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage1 | VST2-1 | FB1=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio1 | MAXDTY1 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio1 | PFMDTY1 | No Load, VPWM1=0V | 22 | 30 | 38 | % | ⑥ |
| Efficiency1 | EFFI1 | IOUT1=100mA, Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑥ |
| Soft-Start Time1 | TSS1 | VOUT1 × 0.95V, CE1=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑥ |
| EXT1 "High" ON Resistance | REXTBH1 | FB1=0, EXT1=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT1 "Low" ON Resistance | REXTBL1 | EN1=FB2=0V, EXT1=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM1 "High" Voltage | VPWMH1 | No Load | 0.65 | - | - | V | ⑥ |
| PWM1 "Low" Voltage | VPWML1 | No Load | - | - | 0.20 | V | ⑥ |

Unless otherwise stated, VDD=EN1=PWM1=3.0V, EN2=PWM2=GND, EXT2=OPEN, FB2=OPEN, VIN=1.8V

**Output 2 Characteristics** Step-up Controller Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|---|---|---|---|---|---|---|---|
| FB2 Voltage | VFB2 | VDD=3.0V, VIN=1.5V, IOUT2=10mA | 0.882 | 0.900 | 0.918 | V | ⑧ |
| Operation Start-up Voltage2 (note 3) | VST1-2 | Using Tr: 2SD1628, IOUT2=1.0mA, RFB21=200kΩ,RFB22=75kΩ | - | - | 0.9 | V | ③ |
| | | VDD ≠ VOUT2 : IOUT2=1mA | - | - | 2.0 | V | ① |
| Oscillation Start-up Voltage2 | VST2-2 | FB2=0V | - | - | 0.8 | V | ④ |
| Maximum Duty Ratio2 | MAXDTY2 | Same as IDD1 | 75 | 80 | 85 | % | ④ |
| PFM Duty Ratio2 | PFMDTY2 | No Load, VPWM2=0V | 22 | 30 | 38 | % | ⑨ |
| Efficiency2 | EFFI2 | IOUT2=100mA, Nch MOSFET:XP161A1355P | - | 83 | - | % | ⑨ |
| Soft-Start Time2 | TSS2 | VOUT2 × 0.95V, EN2=0V→0.65V | 5.0 | 10.0 | 20.0 | mS | ⑨ |
| EXT2 "High" ON Resistance | REXTBH2 | FB2=0, EXT2=VDD-0.4V | - | 28 | 47 | Ω | ⑦ |
| EXT2 "Low" ON Resistance | REXTBL2 | EN2=FB2=0V, EXT2=0.4V | - | 22 | 30 | Ω | ⑦ |
| PWM2 "High" Voltage | VPWMH2 | No Load | 0.65 | - | - | V | ⑨ |
| PWM2 "Low" Voltage | VPWML2 | No Load | - | - | 0.20 | V | ⑨ |

Unless otherwise stated, VDD=EN2=PWM2=3.0V, PWM1=EN1=GND, EXT1=OPEN, FB1=OPEN, VIN=1.8V

Notes

1) Although the IC's step-up operations start from a VDD of 0.8V, the output voltage and switching frequency are stabilized at VDD ≥ 2.0V. Therefore, a VDD of more than 2.0V is recommended when VDD is supplied from VIN or oTher power sources.

2) Although the IC's switching operations start from a VIN of 0.9V, the IC's power supply pin (VDD) and output voltage monitor pin (FB1) should be connected to VOUT1. With operations from VIN=0.9V, the 2nd channel's (output 2) EN2 pin should be set to disable. Once ouput voltage VOUT1 is more than 2.0V, the EN2 pin should be set to enable.

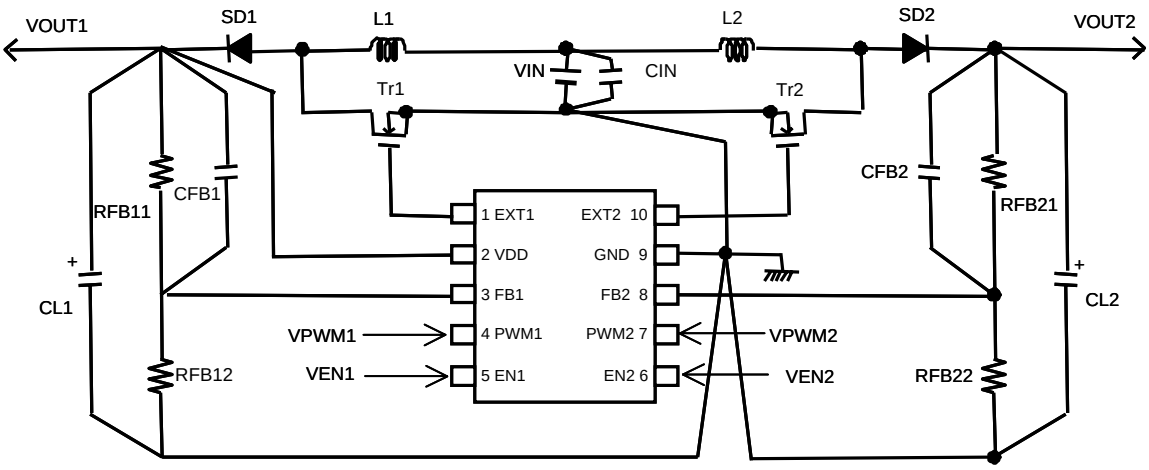
3) Although the IC's switching operations start from a VIN of 0.9V, the IC's power supply pin (VDD) and output voltage monitor pin (FB2) should be connected to VOUT2. With operations from VIN=0.9V, the 1st channel's (output 1) EN1 pin should be set to disable. Once ouput voltage VOUT2 is more than 2.0V, the EN1 pin should be set to enable.

4) Please be careful not to exceed the breakdown voltage level of the peripheral parts.

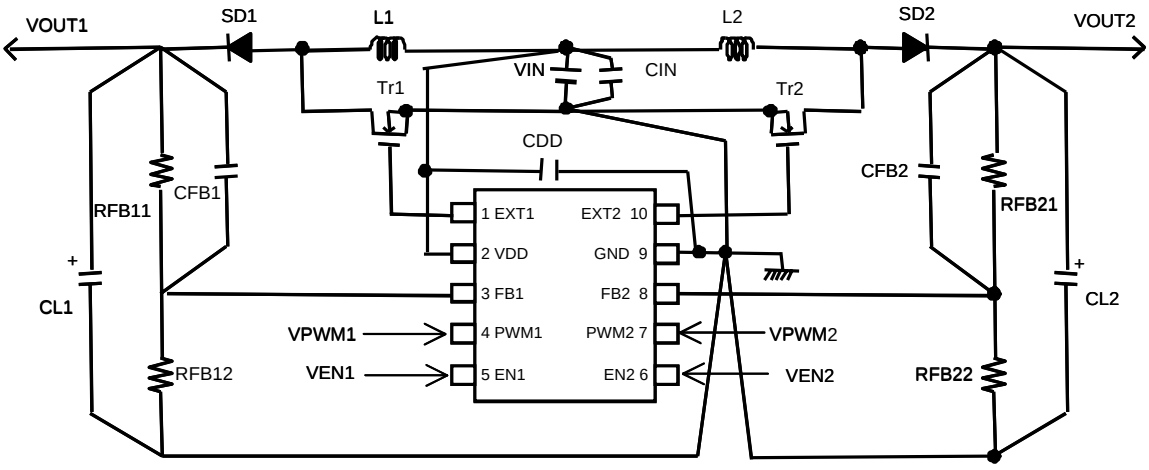
5) EFFI={ [ (Output voltage) x (Output current) ] / [ (Input voltage) x (Input Current) ] } x 100

## ■ Typical Application Circuit

① VDD connected to VOUT1




② VDD connected to VIN



## ■ Operation Description

The XC9501 series are multi-functional, 2 channel step-up DC/DC converter controller ICs with built-in high speed, low ON resistance drivers.

**<Error Amp>**
The Error Amplifier is designed to monitor the output voltage and it compares the feedback voltage (FB) with the reference voltage. In response to feedback of a voltage lower than the reference voltage, the output voltage of the error amp. decreases.

**<OSC Generator>**
This circuit generates the Switching Frequency which in turn generates the reference clock.

**<Ramp Wave Generator 1, 2>**
The Ramp Wave Generator generates a saw-tooth waveform based on outputs from the Phase Shift Generator.

**<PWM Comparator 1, 2>**
The PWM Comparator compares outputs from the Error Amp. and saw-tooth waveform. When the voltage from the Error Amp's output is low, the external switch will be set to ON.

**<PWM/PFM Controller 1, 2>**
This circuit generates PFM pulses.
Control can be switched between PWM control and PWM/PFM automatic switching control using external signals.
The PWM/PFM automatic switching mode is selected when the voltage of the PWM1 (2) pin is less than 0.2V, and the control switches between PWM and PFM automatically depending on the load. As the PFM circuit generates pulses based on outputs from the PWM comparator, shifting between modes occurs smoothly. PWM control mode is selected when the voltage of the PWM1 (2) pin is more than 0.65V. Noise is easily reduced with PWM control since the switching frequency is fixed.
Control suited to the application can easily be selected which is useful in audio applications, for example, where traditionally, efficiencies have been sacrificed during stand-by as a result of using PWM control (due to the noise problems associated with the PFM mode in stand-by).

**<Vref with Soft Start 1, 2>**
The reference voltage, Vref (FB pin voltage)=0.9V, is adjusted and fixed by laser trimming (for output voltage settings, please refer to the notes on page 8). To protect against inrush current, when the power is switched on, and also to protect against voltage overshoot, soft-start time is set internally to 10ms. It should be noted, however, that this circuit does not protect the load capacitor (CL) from inrush current. With the Vref voltage limited and depending upon the input to the error amps, the operation maintains a balance between the two inputs of the error amps and controls the EXT pin's ON time so that it doesn't increase more than is necessary.

**<Enable Function>**
This function controls the operation and shutdown of the IC. When the voltage of the EN1 or EN2 pins is 0.2V or less, the mode will be disable, the channel's operations will stop and the EXT1 pin will be kept at a low level (the external N-type MOSFET will be OFF). When both EN1 and EN2 are in a state of disable, current consumption will be no more than 3.0 μA.
When the EN1 or EN2 pin's voltage is 0.65V or more, the mode will be enable and operations will recommence. With soft-start, 95% of the set output voltage will be reached within 10mS (TYP) from the moment of enable.

The start-up sequence for EN1 and EN2 is required when operations begin with a power supply voltage of VDD<2.0V or less. Although IC starts oscillation from a VIN of 0.9V, the IC's power supply pin (VDD) and the output voltage monitor pin (FB1) should be connected to VOUT1. When the IC starts operations from a VIN of 0.9V, set channel two's (output 2) EN2 pin to disable and turn it to enable when VOUT1 is more than 2.0V. Conversely, when IC 2's power supply pin (VDD) and output voltage monitor
pin (FB2) are connected to VOUT2, set channel one's (output 1) EN1 pin to disable and turn it to enable when VOUT2 is more than
2.0V.
For power supply voltages of VDD<2.0V, oscillation may occur irrespective of the FB pin voltage. Should this happen, you may find that output voltage will be higher than the set voltage. The FB pin voltage and the reference voltage Vref will be compared and output voltage will be controlled when the power supply voltage is VDD>2.0V or more. With power supply voltages of VDD>2.0V, the start-up sequence for EN1 and EN2 will not be required.

**<Setting of Output Voltage>**

Output voltage can be set by adding external split resistors. Output voltage is determined by the following equation, based on the values of RFB11(RFB21) and RFB12(RFB22). The sum of RFB11(RFB21) and RFB12(RFB22) should normally be 1 MΩ or less.

$$V_{OUT}=0.9 \times (RFB11+RFB12) / RFB12$$

The value of CFB1(CFB2), speed-up capacitor for phase compensation, should be resulted fzfb = 1 / (2 π x CFB1 x RFB11) equal to 12kMz. Adjustments are required from 1kHz to 50kHz depending on the application, value of inductance (L), and value of load capacity (CL).

**[Example of Calculation]**

When RFB11=200kΩ and RFB12=75kΩ, $V_{OUT1}=0.9 \times (200K+75k) / 75k=3.3V$.

**[Typical Example]**

| VOUT (V) | RFB11 (kΩ) | RFB12 (kΩ) | CFB1 (pF) | VOUT (V) | RFB11 (kΩ) | RFB12 (kΩ) | CFB1 (pF) | VOUT (V) | RFB11 (kΩ) | RFB12 (kΩ) | CFB1 (pF) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 220 | 330 | 62 | 2.7 | 360 | 180 | 33 | 12.0 | 160 | 13 | 82 |
| 1.8 | 220 | 220 | 62 | 3.0 | 560 | 240 | 24 | | | | |
| 2.0 | 330 | 270 | 39 | 3.3 | 200 | 75 | 62 | | | | |
| 2.2 | 390 | 270 | 33 | 5.0 | 82 | 18 | 160 | | | | |
| 2.5 | 390 | 220 | 33 | 8.0 | 120 | 15 | 100 | | | | |

The same method can be adopted for channel two (output 2) also.

**[External Components]**

Tr : * MOSFET

XP161A1355PR (TOREX N-Channel Power MOSFET)

Note : VGS Breakdown Voltage of this Tr. is 8V so please be careful with the power supply voltage. If the power supply voltage is more than 6V, please use XP161A1265PR, where VGS Breakdown Voltage is 12V. VST1 of XP161A1355PR is 1.2V (max.) and that of XP161A1265PR is 1.5V (max.)

* NPN MOSFET

2SD1628 (SANYO)

Rb : 500Ω

( Adjust in accordance with load & Tr.'s HFE.)

Cb : 2200pF (Ceramic)

Set up according to the equation below.

Cb ≤1/(2 π × Rb × Fosc × 0.7)

SD : MA2Q737 (Schottky , MATSUSHITA)

CMS02 (Schottky , TOSHIBA)

L : 22μH (SUMIDA, CDRH5D28, FOSC = 180kHz)

15μH (SUMIDA, CDRH5D28, FOSC = 300kHz)

10μH (SUMIDA, CDRH5D28, FOSC = 500kHz)

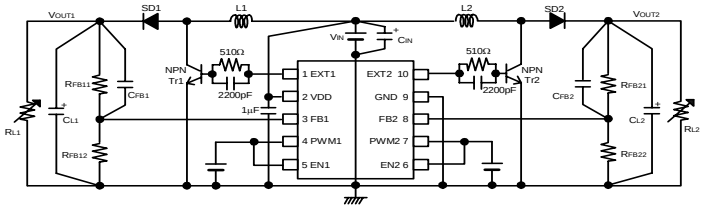
CL : 16V, 47μF (Tantalum, NICHICHEMI MCE series)

Increase capacity according to the equation below when the step-up voltage ratio is large and output current is high.

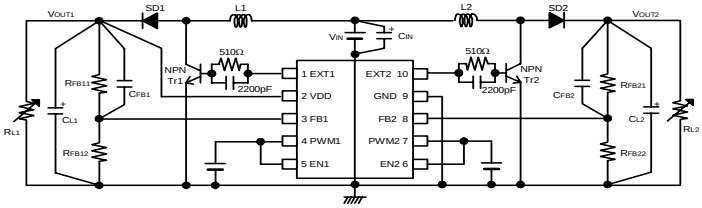
$$CL = (CL\ standard\ value) \times (I_{OUT}\ (mA) / 300mA \times V_{OUT}/V_{IN}$$

## ■ Test Circuit

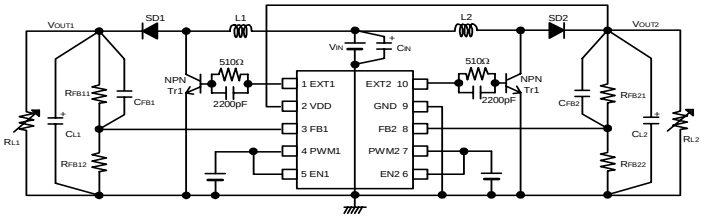
### Circuit 1



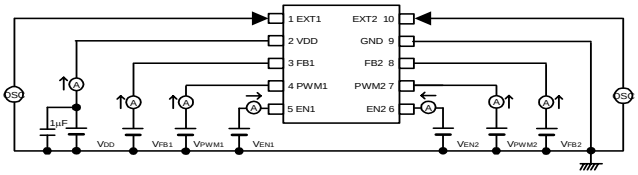

### Circuit 2



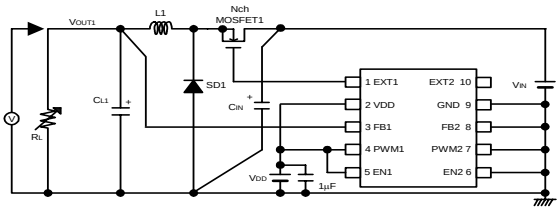

### Circuit 3



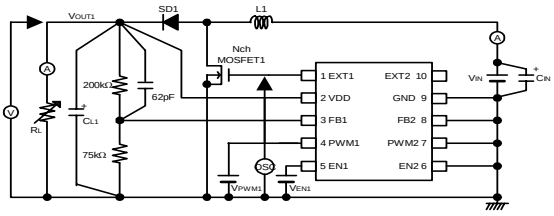

### Circuit 4



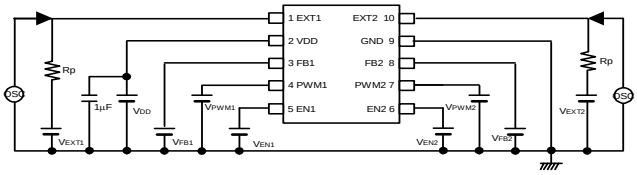

### Circuit 5



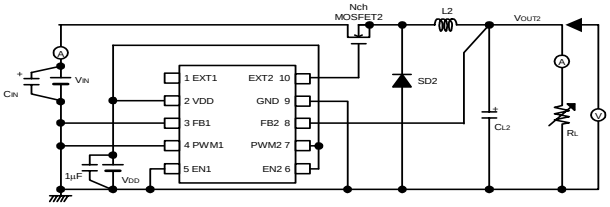

### Circuit 6



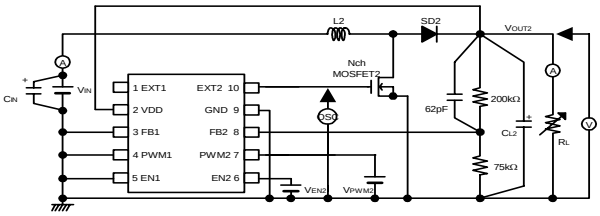

### Circuit 7




### Circuit 8




### Circuit 9



## ■ Peripheral Components Used for Test Circuits

Circuit 1, Circuit 2, Circuit 3

| | |
|---|---|
| L1, L2 : | 22μH (SUMIDA CDRH5D28) : XC9501B092A |
| | 15μH (SUMIDA CDRH5D28) : XC9501B093A |
| | 10μH (SUMIDA CDRH5D28) : XC9501B095A |
| SD1, SD2 : | CRS02 (Schottky diode, TOSHIBA) |
| | EC10QS06 (Schottky diode, NIHON INTER) |
| CL1, CL2 : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| | 35MCE335MB2 (Tantalum, NIHON CHEMICON) |
| CIN : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| NPN Tr1, 2: | 2SA1628 (SANYO) |
| | CPH3215 (SANYO) |
| | CPH3210 (SANYO) |
| RFB : | Please use by the conditions as below. |
| | RFB11 + RFB12 ≤ 1MΩ |
| | RFB21 + RFB22 ≤ 1MΩ |
| | RFB11 / RFB12 = (Setting Output Voltage / 0.9) -1 |
| | RFB21 / RFB22 = (Setting Output Voltage / 0.9) -1 |
| CFB : | Please adjust as below: |
| | fzfb=1/(2 x π x CFB1 x RFB11) = 1kHz ~50kHz ( 12kHz usual) |
| | fzfb=1/(2 x π x CFB2 x RFB21) = 1kHz ~50kHz ( 12kHz usual) |

Circuit 6 and Circuit 9

| | |
|---|---|
| L1, L2 : | 22μH (SUMIDA CDRH5D28) : XC9501B092A |
| | 15μH (SUMIDA CDRH5D28) : XC9501B093A |
| | 10μH (SUMIDA CDRH5D28) : XC9501B095A |
| SD1, SD2: | MA2Q737 (Schottky diode, MATSUSHITA) |
| CL1, CL2 : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| CIN : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| N-ch MOSFET1 : | XP161A1355P (TOREX) |

Circuit 5 and Circuit 8

| | |
|---|---|
| L1, L2 : | 22μH (SUMIDA CDRH5D28) |
| SD1, SD2 : | MA2Q737 (Schottky, MATSUSHITA) |
| CL1, CL2 : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| CIN : | 16MCE476MD2 (Tantalum, NIHON CHEMICON) |
| N-ch MOSFET1 : | XP161A1355P (TOREX) |

## ■ Notes on Use

1. PWM/PFM Automatic Switching

If PWM/PFM automatic switching control is selected and the step-up ratio is low (e.g., from 4.5 V to 5.0 V), the control mode remains in PFM setting over the whole load range, since the duty ratio under continuous-duty condition is smaller than the PFM duty ratio of the XC9501 series. The output voltage's ripple voltage becomes substantially high under heavy load conditions, with the XC9501 series appearing to be producing an abnormal oscillation. If this operation becomes a concern, set pins PWM to High to set the control mode to PWM setting. For use under the above-mentioned condition, measured data of PWM/PFM automatic switching control shown on the data sheets are available up to IOUT = 100 mA.

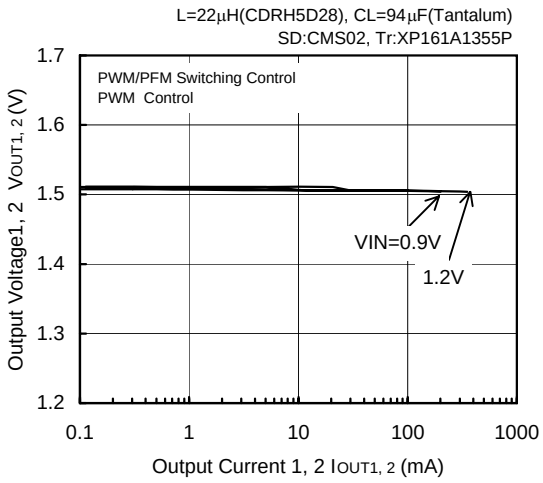
3. Ratings

Use the XC9501 series and peripheral components within the limits of their ratings.

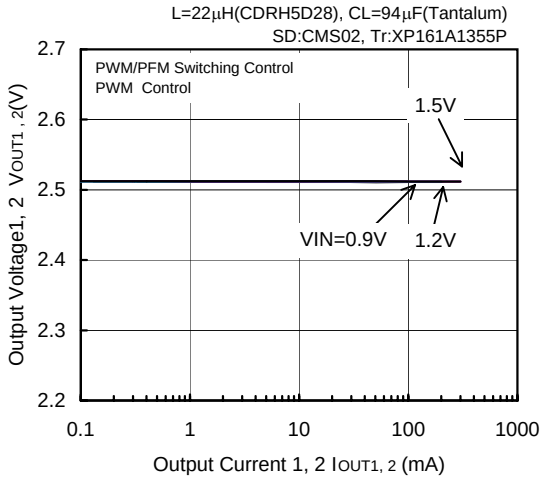
■ Typical Performance Characteristics

(1) Output Voltage vs. Output Current

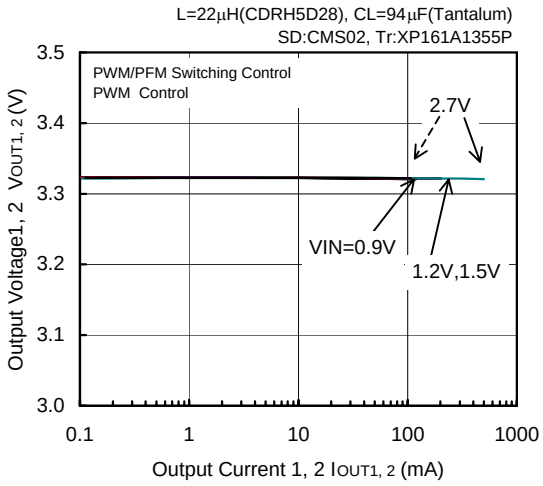
**FOSC=180kHz, VOUT1, 2= 1.5V**



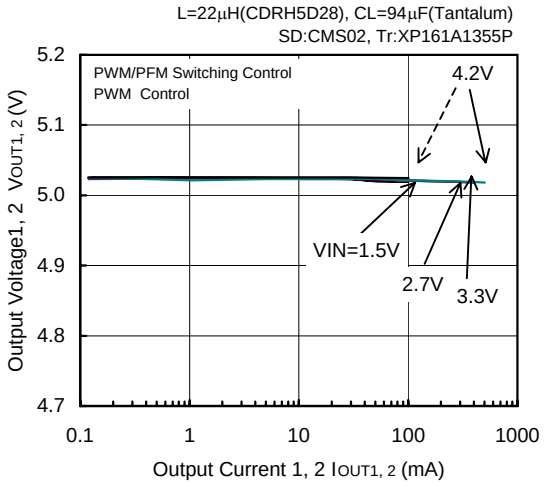

**FOSC=180kHz, VOUT1, 2= 2.5V**



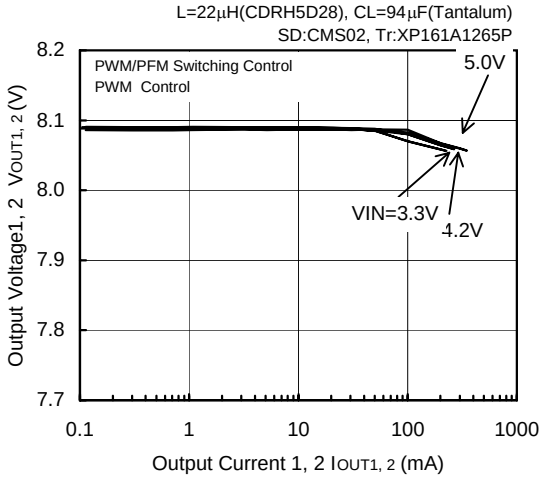

**FOSC=180kHz, VOUT1, 2= 3.3V**




**FOSC=180kHz, VOUT1, 2= 5.0V**



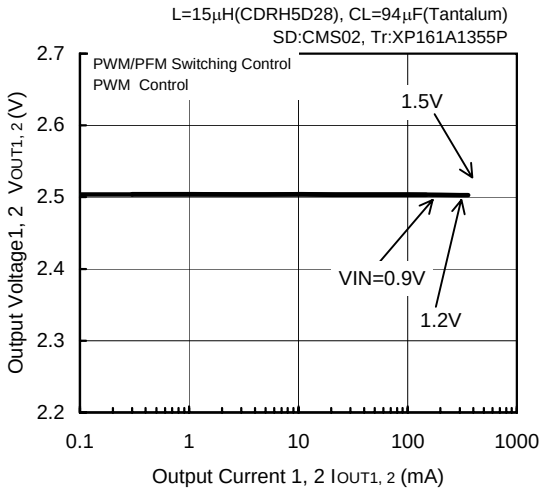

**FOSC=180kHz, VOUT1, 2= 8.0V**



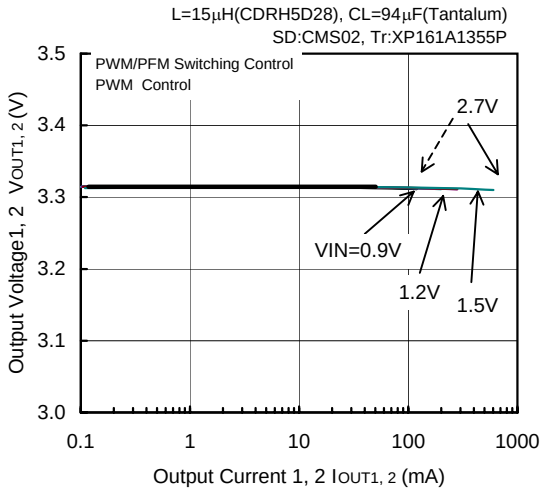

Dotted Arrowhead ----> PWM/PFM Switching Control

(1) Output Voltage vs. Output Current (Continued)

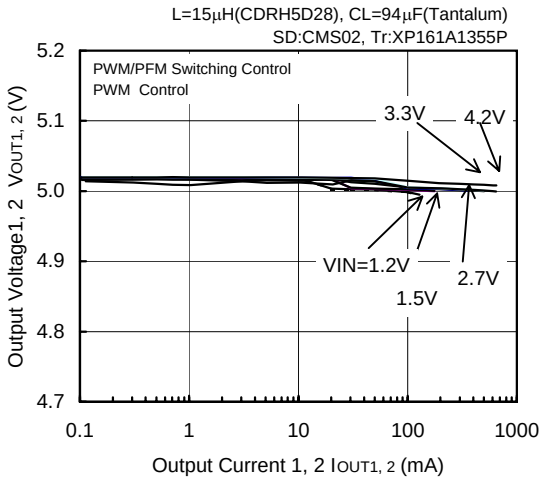
**FOSC=300kHz, VOUT1, 2= 2.5V**



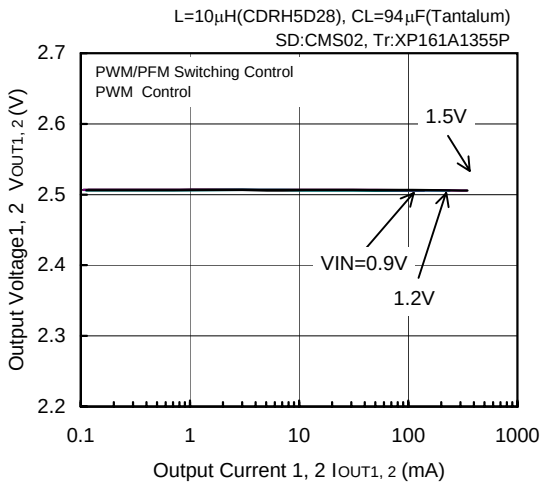

**FOSC=300kHz, VOUT1, 2= 3.3V**



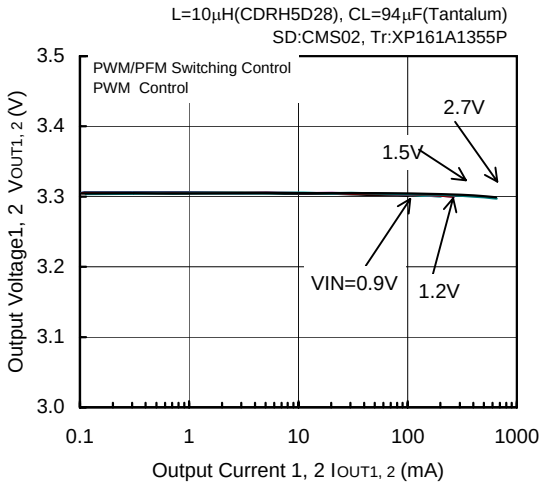

**FOSC=300kHz, VOUT1, 2= 5.0V**



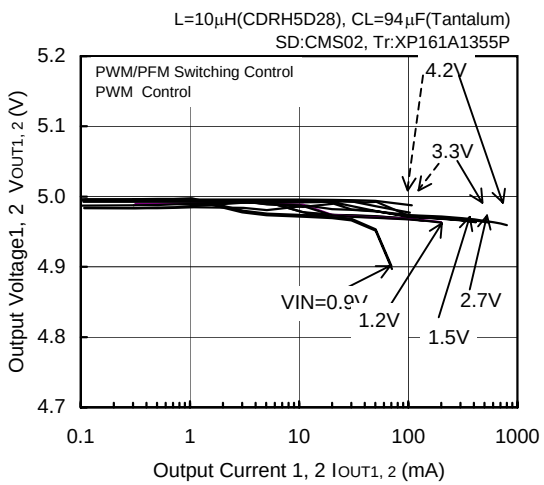

**FOSC=500kHz, VOUT1, 2= 2.5V**




**FOSC=500kHz, VOUT1, 2= 3.3V**



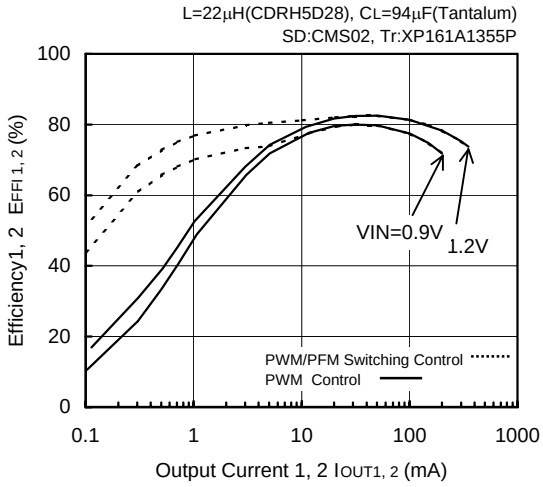

**FOSC=500kHz, VOUT1, 2= 5.0V**



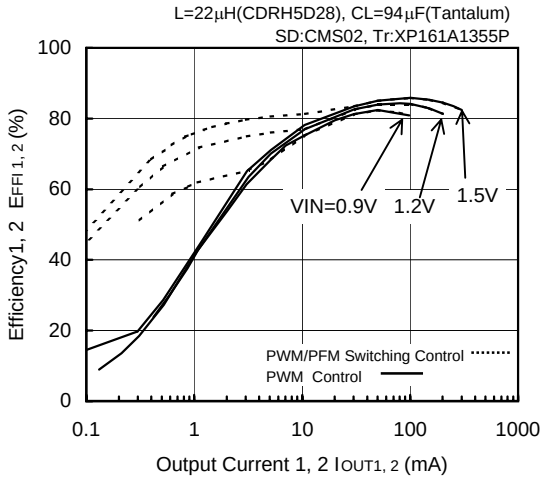

Dotted Arrowhead ----> PWM/PFM Switching Control

(2) Efficiency vs. Output Current

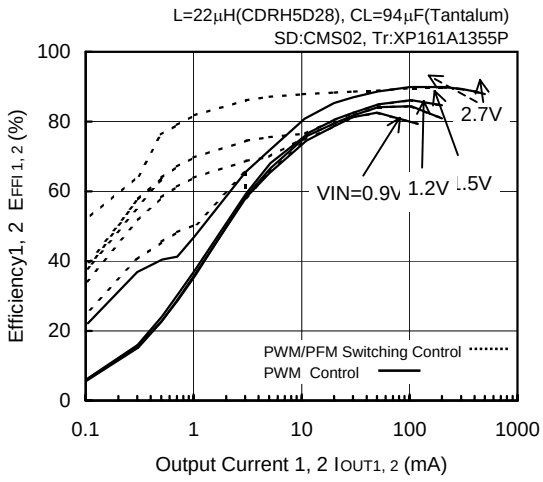
**FOSC=180kHz, VOUT1, 2= 1.5V**



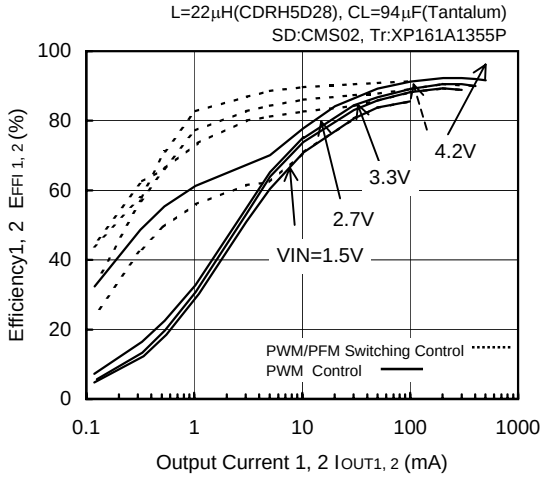

**FOSC=180kHz, VOUT1, 2= 2.5V**



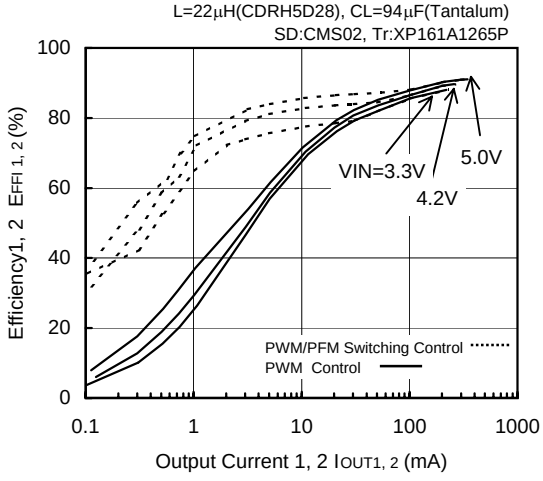

**FOSC=180kHz, VOUT1, 2= 3.3V**




**FOSC=180kHz, VOUT1, 2= 5.0V**



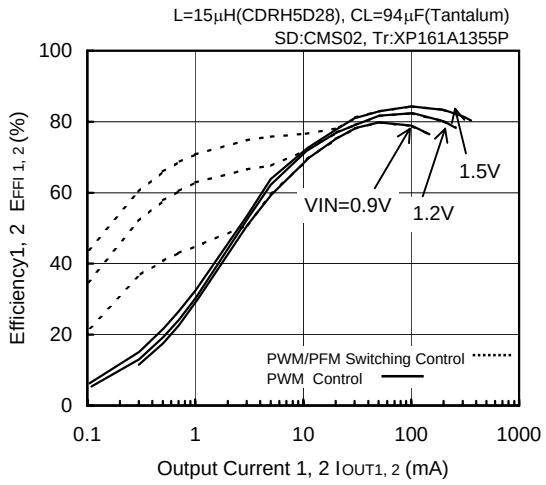

**FOSC=180kHz, VOUT1, 2= 8.0V**



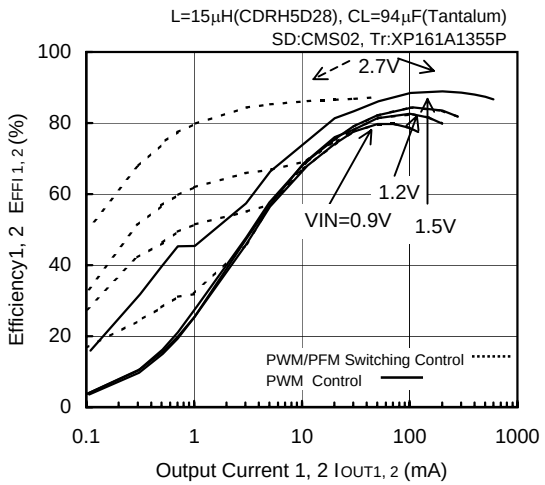

Dotted Arrowhead ----> PWM/PFM Switching Control

(2) Efficiency vs. Output Current (Continued)

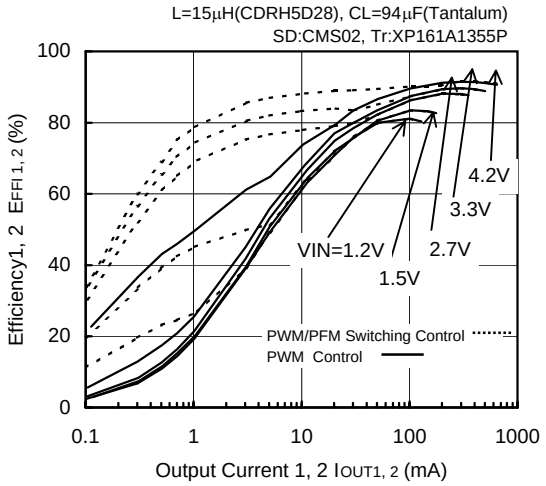
**FOSC=300kHz, VOUT1, 2= 2.5V**



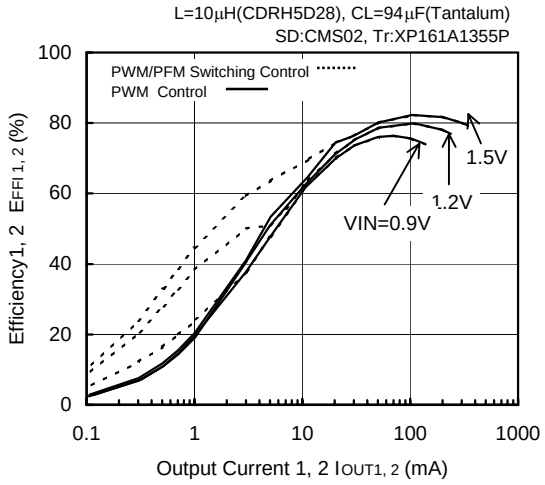

**FOSC=300kHz, VOUT1, 2= 3.3V**



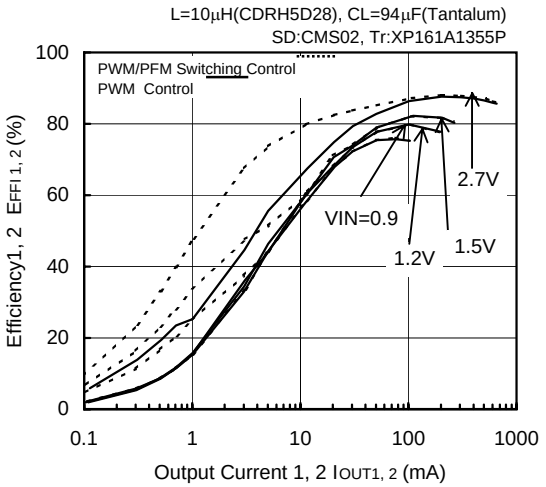

**FOSC=300kHz, VOUT1, 2= 5.0V**



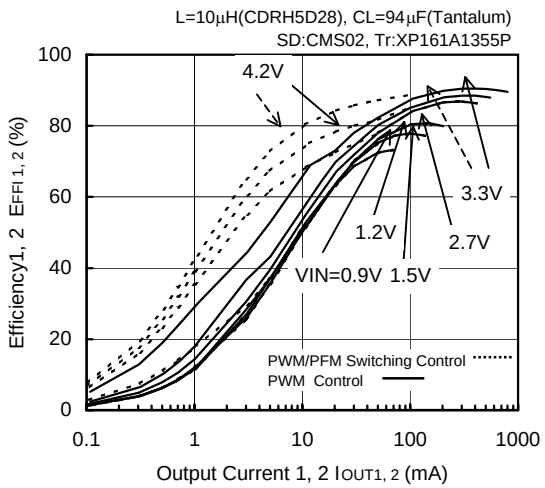

**FOSC=500kHz, VOUT1, 2= 2.5V**




**FOSC=500kHz, VOUT1, 2= 3.3V**



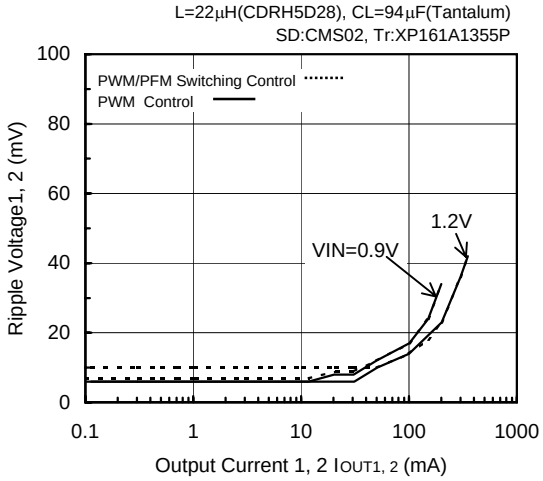

**FOSC=500kHz, VOUT1, 2= 5.0V**



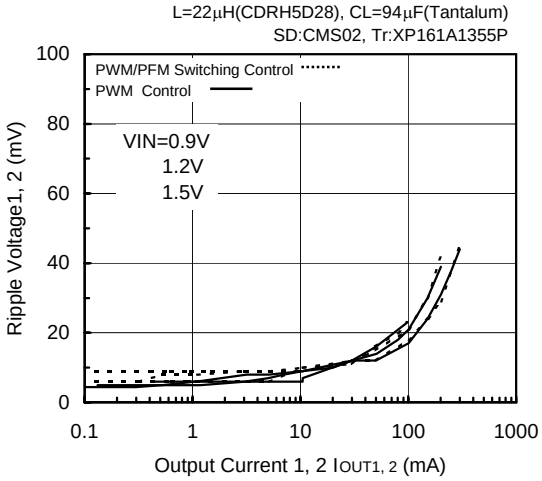

Dotted Arrowhead ----> PWM/PFM Switching Control

(3) Ripple Voltage vs. Output Current

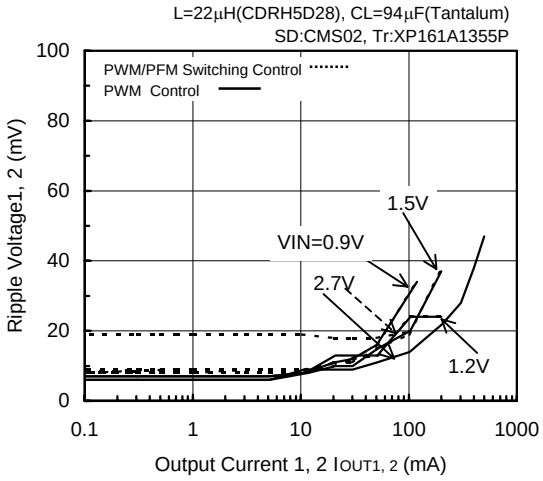
**FOSC=180kHz, VOUT1, 2= 1.5V**



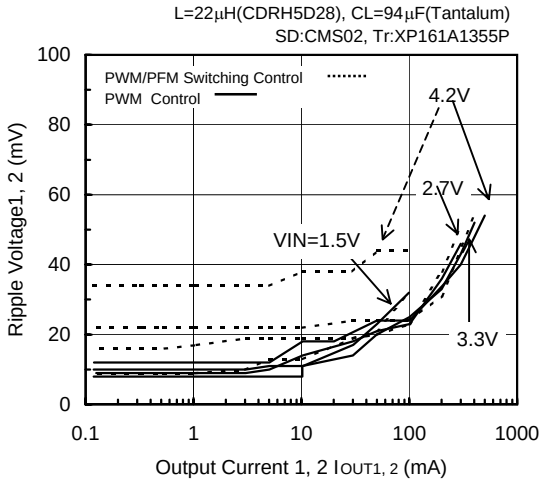

**FOSC=180kHz, VOUT1, 2= 2.5V**



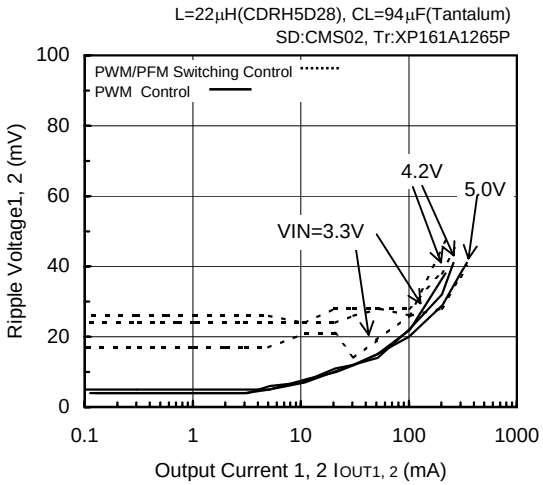

**FOSC=180kHz, VOUT1, 2= 3.3V**




**FOSC=180kHz, VOUT1, 2= 5.0V**



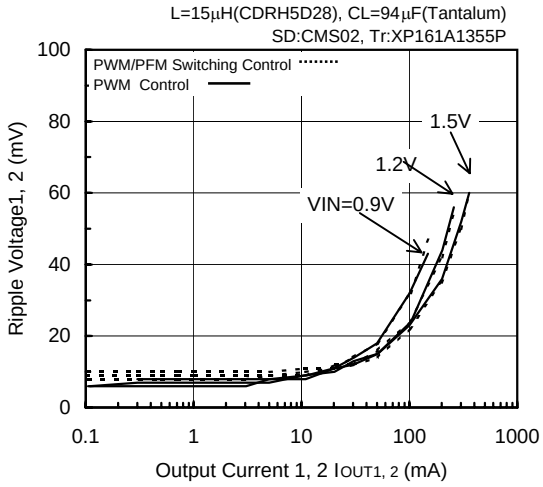

**FOSC=180kHz, VOUT1, 2= 8.0V**



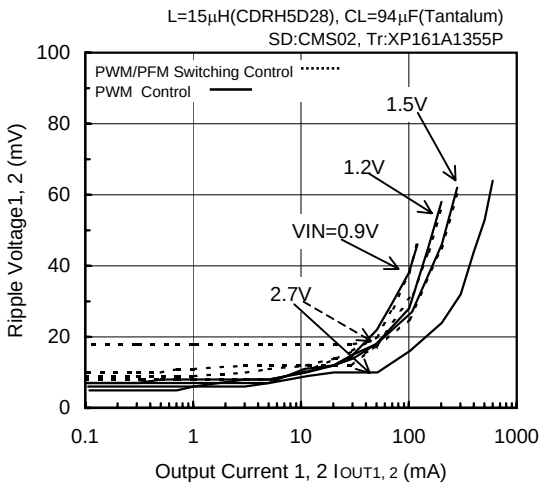

Dotted Arrowhead ----> PWM/PFM Switching Control

(3) Ripple Voltage vs. Output Current (Continued)

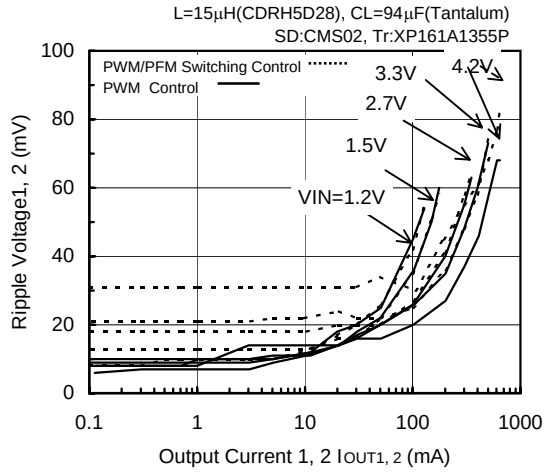
**FOSC=300kHz, VOUT1, 2= 2.5V**



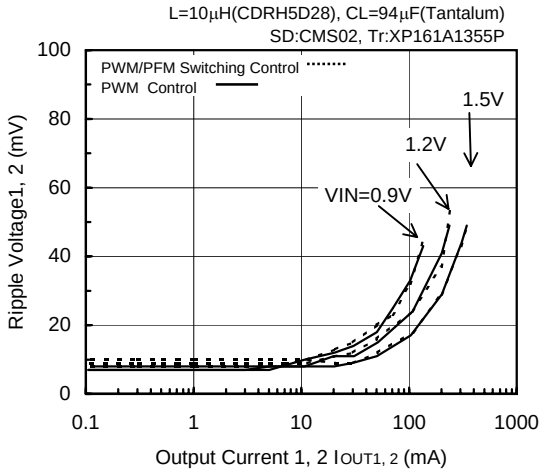

**FOSC=300kHz, VOUT1, 2= 3.3V**



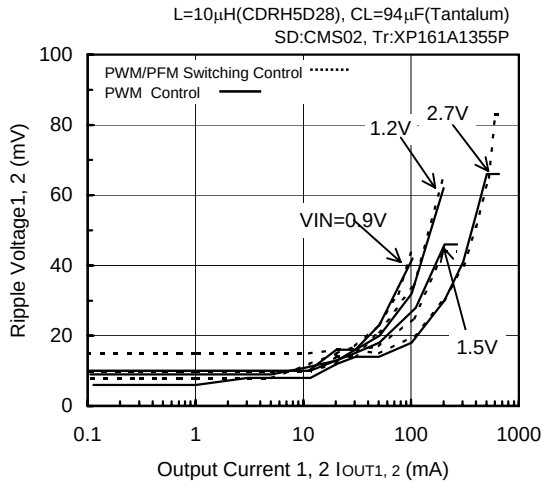

**FOSC=300kHz, VOUT1, 2= 5.0V**



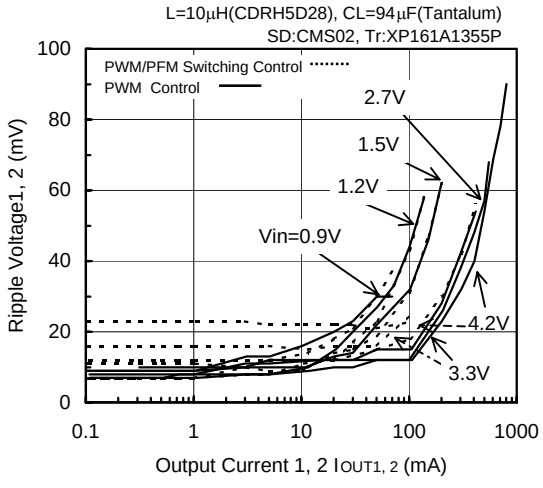

**FOSC=500kHz, VOUT1, 2= 2.5V**




**FOSC=500kHz, VOUT1, 2= 3.3V**




**FOSC=500kHz, VOUT1, 2= 5.0V**

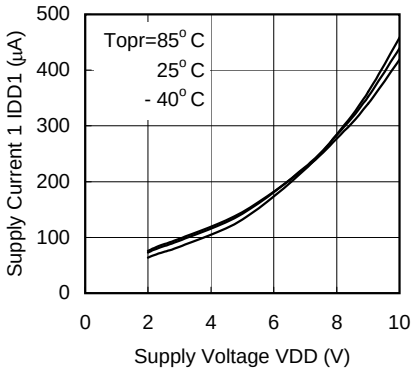



Dotted Arrowhead ----> PWM/PFM Switching Control

■ Typical Performance Characteristics (Continued)

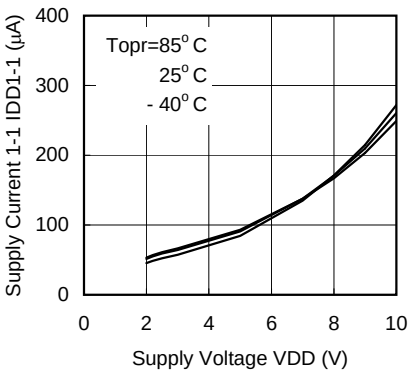
(4) Supply Current vs. Supply Voltage

**XC9501B092 (180kHz)**



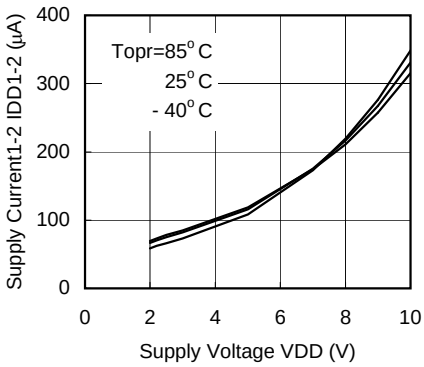

(5) Supply Current 1-1 vs. Supply Voltage

**XC9501B092 (180kHz)**



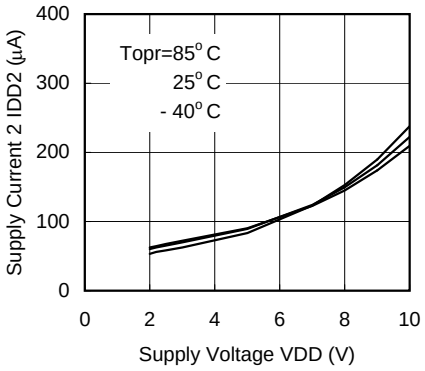

(6) Supply Current 1-2 vs. Supply Voltage

**XC9501B092 (180kHz)**



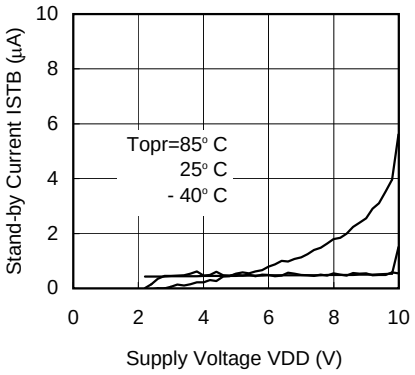

(7) Supply Current 2 vs. Supply Voltage

**XC9501B092 (180kHz)**



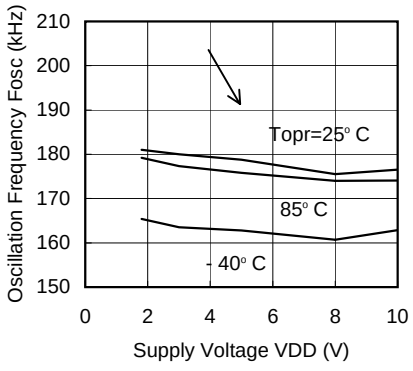

(8) Stand-by Current vs. Supply Voltage

**XC9501B092 (180kHz)**



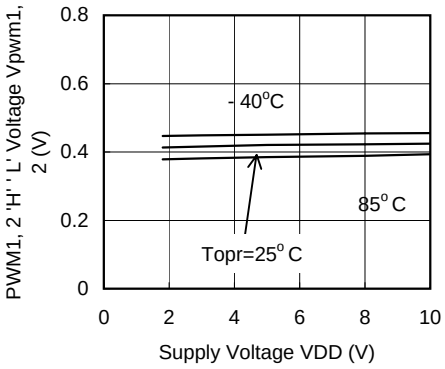

(9) Oscillation Frequency vs. Supply Voltage

**XC9501B092 (180kHz)**



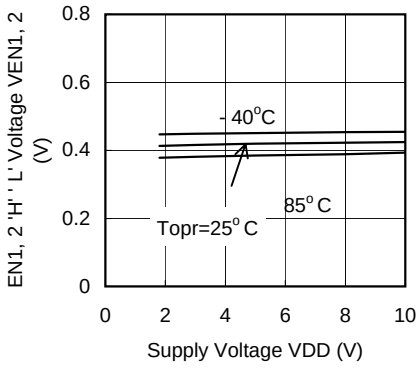
(10) PWM1, 2 'H' 'L' Voltage vs. Supply Voltage

**XC9501B092 (180kHz)**



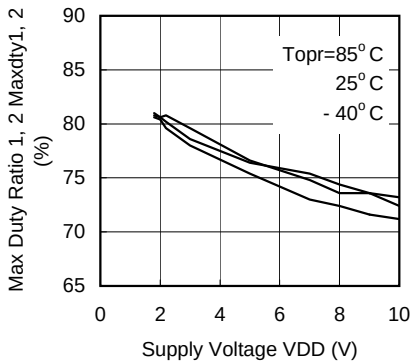

(11) EN1, 2 'H' 'L' Voltage vs. Supply Voltage

**XC9501B092 (180kHz)**



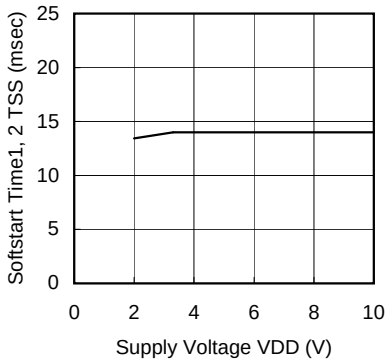

(12) Maximum Duty Ratio1, 2 vs. Supply Voltage

**XC9501B092 (180kHz)**



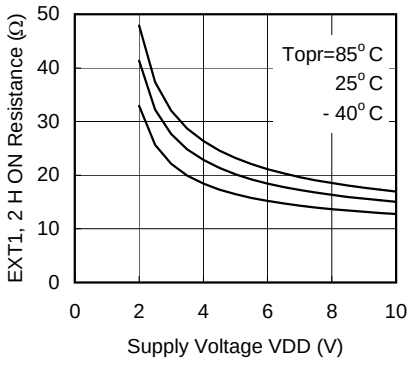

(13) Softstart Time1, 3 vs. Supply Voltage

**XC9501B092 (180kHz)**



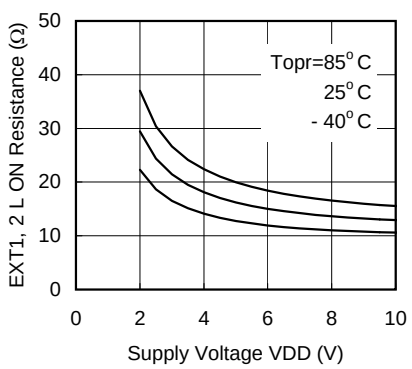

(14) EXT1, 2 High ON Resistance vs. Supply Voltage

**XC9501B092 (180kHz)**

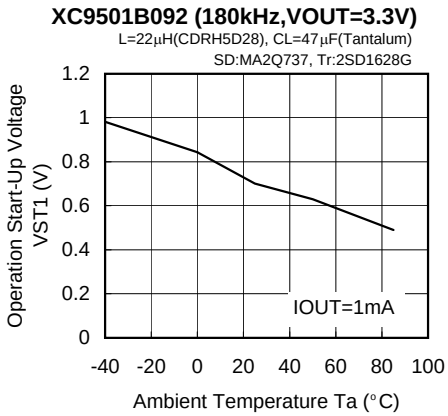



(15) EXT1, 2 Low ON Resistance vs. Supply Voltage

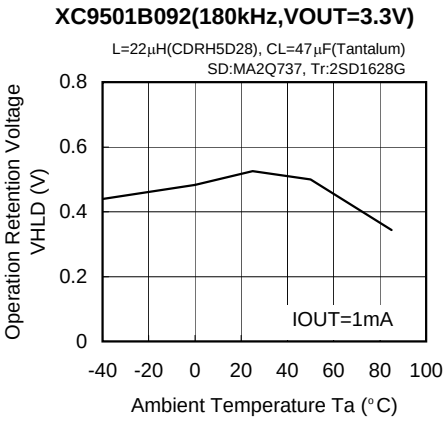
**XC9501B092 (180kHz)**



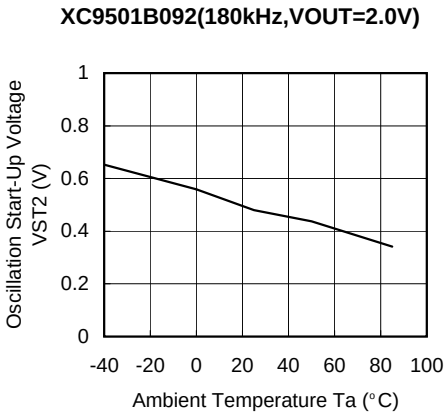
(16) Operation Start-Up Voltage vs. Ambient Temperature



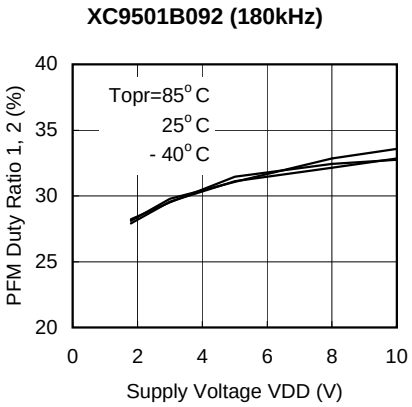

(17) Operation Retention Voltage vs. Ambient Temperature



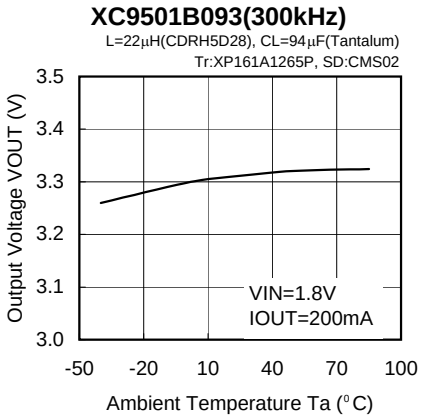

(18) Oscillation Start-Up Voltage vs. Ambient Temperature




(19) PFM Duty Ratio 1, 2 vs. Supply Voltage




(20) Output Voltage vs. Ambient Temperature

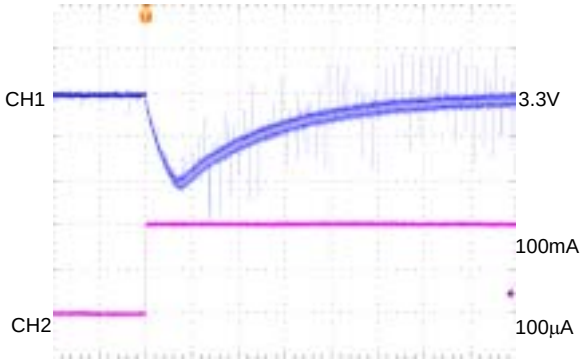


■ Load Transient Response

< VOUT1 = 3.3V, VIN = 2.0V IOUT1, 2 =100μA ⇔ 100mA >

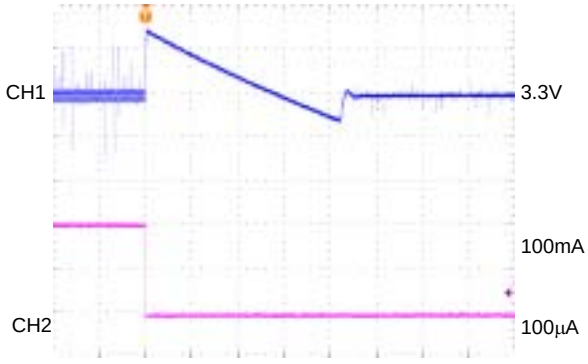
❍ PWM Control

FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100μA→ 100mA




200μsec/div
CH1:VOUT1 , 2, AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

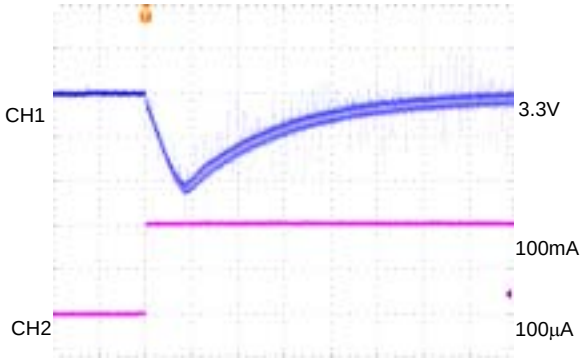
FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100mA→ 100μA




10msec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

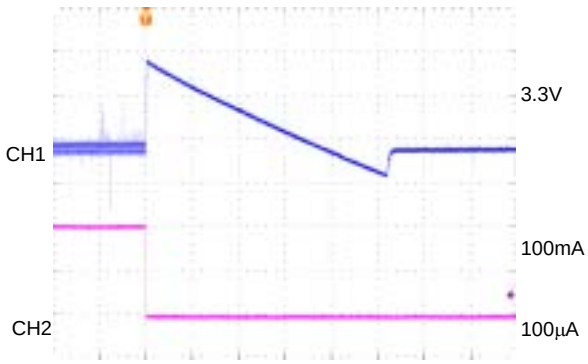
❍ PWM/PFM Switching Control

FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100μA→ 100mA




200μsec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100mA→ 100μA

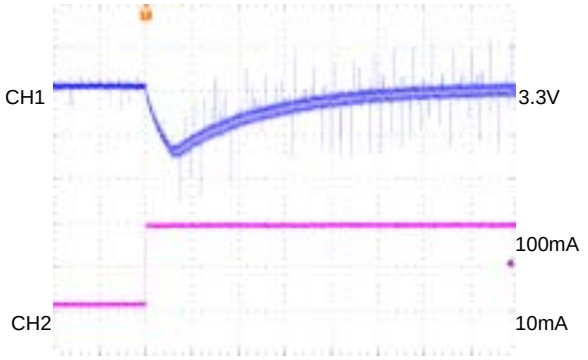



10msec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

< VOUT1 = 3.3V, VIN = 2.0V IOUT1, 2 =10mA ⇔ 100mA >

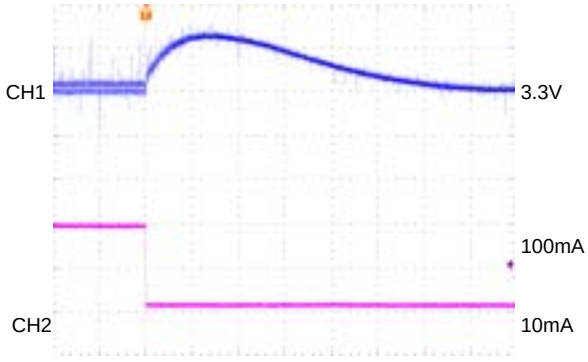
❍ PWM Control

FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=10mA→ 100mA




200μsec/div
CH1:VOUT1 , 2, AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

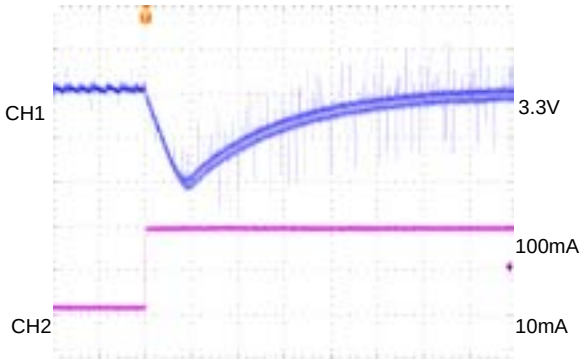
FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100mA→ 10mA




200μsec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

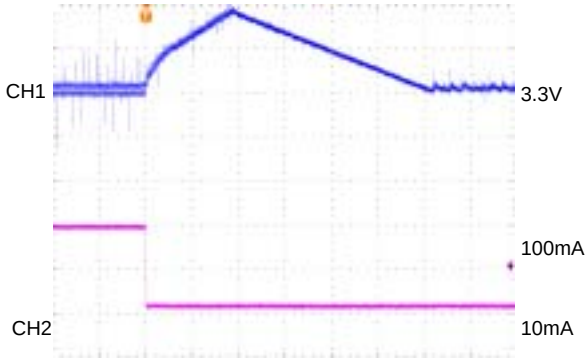
❍ PWM/PFM Switching Control

FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=10mA→100mA




200μsec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

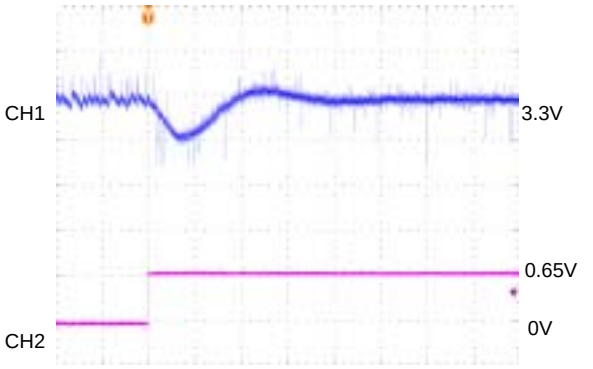
FOSC=180kHz, VOUT1, 2=3.3V
VIN=2.0V, IOUT1, 2=100mA→ 10mA




200μsec/div
CH1:VOUT1, 2 , AC-COUPLED, 50mV/div
CH2:IOUT1, 2 , 50mA/div

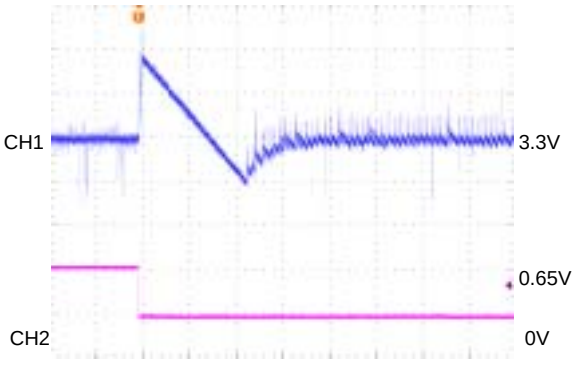
< PWM Controlled ⇔ PWM / PFM Switching Controlled >

FOSC=180kH, $V_{OUT1, 2}$=3.3V
VIN=2.0V, $I_{OUT1, 2}$=1mA PWM1, 2, 'L'→'H'




1msec/div
CH1:$V_{OUT1, 2}$ , AC-COUPLED ,10mV/div
CH2:$PWM_{1, 2}$ , 0.5V/div

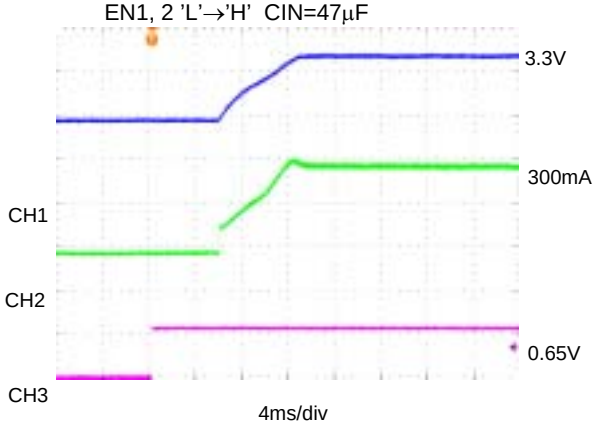
FOSC=180kHz, $V_{OUT1, 2}$=3.3V
VIN=2.0V, $I_{OUT1, 2}$=1mA PWM1, 2, 'H'→'L'




1msec/div
CH1:$V_{OUT1, 2}$ , AC-COUPLED ,10mV/div
CH2:$PWM_{1, 2}$ , 0.5V/div

❍ Soft Start Wave Form

FOSC=180kHz, $V_{OUT1, 2}$=3.3V
VIN=2.0V, $I_{OUT1, 2}$=100mA
EN1, 2 'L'→'H' CIN=47μF




4ms/div
CH1:$V_{OUT1, 2}$ , 1.0V/div
CH2:$I_{IN1, 2}$ , 100mA/div
CH3:EN1, 2 , 0.5V/div

* CH1: EN2=GND when measurement
CH2: EN1=GND when measurement