RM590L Series

400mA Synchronous Step-down DC/DC Module with MODE pin and Inductor

No.EA-592-231209

OVERVIEW

The RM590L is a synchronous, step-down DC/DC converter which delivers up to 400mA of output current. The RM590L can be configured for either PWM/VFM automatic shift operation or forced PWM operation by controlling of MODE pin. This device has a built-in inductor (0.5μH, DCR=0.125Ω (TYP)) and is available in 2.2 (mm) x 2.0 (mm) x 1.5 (mm) sized QFN2220-8 package for high density mounting. Therefore, it is possible to save space in the mounting area.

KEY BENEFITS

- Having an inductor built-in, it is possible to simplify the board design and reduce the mounting area.
- PWM/VFM automatic shift operation provides high efficiency at light loads.
- Having an inductor built-in, the number of parts can be reduced, and the man-hours for managing purchased parts can be reduced (concern about EOL).

KEY SPECIFICATIONS

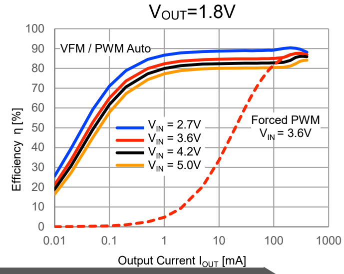
- Input Voltage Range (Maximum Rating):
  2.3 V to 5.5 V (6.5 V)
- Output Voltage (Fixed Output Voltages):
  from 0.6V to 3.3V in 0.1V increments
  ±1.5% (V_{SET} ≥ 1.2 V), ±18 mV (V_{SET} < 1.2 V)
  Output Voltage Accuracy
- Output Voltage (Adjustable Output Voltages):
  0.6 V to 5.5 V
  0.6V Reference (VFB), ±9 mV Voltage Accuracy
- Selectable Oscillator Frequency: Typ. 6.0 MHz
- Oscillator Maximum Duty: Min. 100%
- MOSFET ON Resistance (V_{IN} = 3.6 V):
  High Side MOSFET Typ. 0.245 Ω
  Low Side MOSFET Typ. 0.225 Ω
- UVLO Detector Threshold: Typ. 2.0 V
- Soft-start Time: Typ. 0.15 ms
- Thermal Shutdown Function:
  Detection Temperature 140°C
  Release Temperature 100°C

PACKAGE

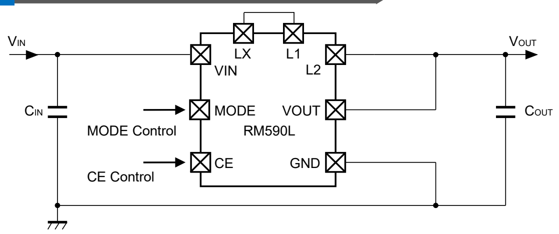
QFN2220-8
2.2 x 2.0 x 1.5 (mm)

TYPICAL CHARACTERISTICS

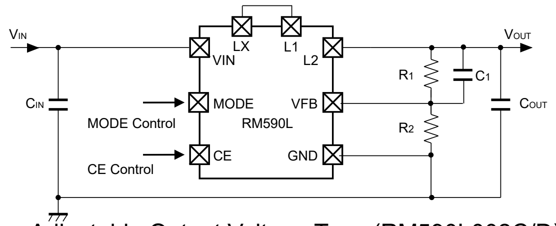
Efficiency
V_{OUT}=1.8V



TYPICAL APPLICATIONS



Fixed Output Voltage Type (RM590Lxx2A/B)



Adjustable Output Voltage Type (RM590L002C/D)

APPLICATIONS

- Devices need to be miniaturized such as wearables, hearables
- Phones, domestic LAN systems
- Communication modules, and applications for Industrial equipment
- Instrumentation equipment such as flow meters and pressure gauges

SELECTION GUIDE

The set output voltage, the output voltage type, and the auto-discharge function are user-selectable options.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RM590Lxx2$-TR	QFN2220-8	2,000	Yes	Yes

xx : Set Output Voltage (V_{SET})

Fixed Output Voltage Type : 06 to 33 (0.6 V to 3.3 V, 0.1 V steps)
The voltage in 0.05 V step is shown as follows.
Ex. 1.25 V: RM590L122$5
Refer to *Product-specific Electrical Characteristics* for details.

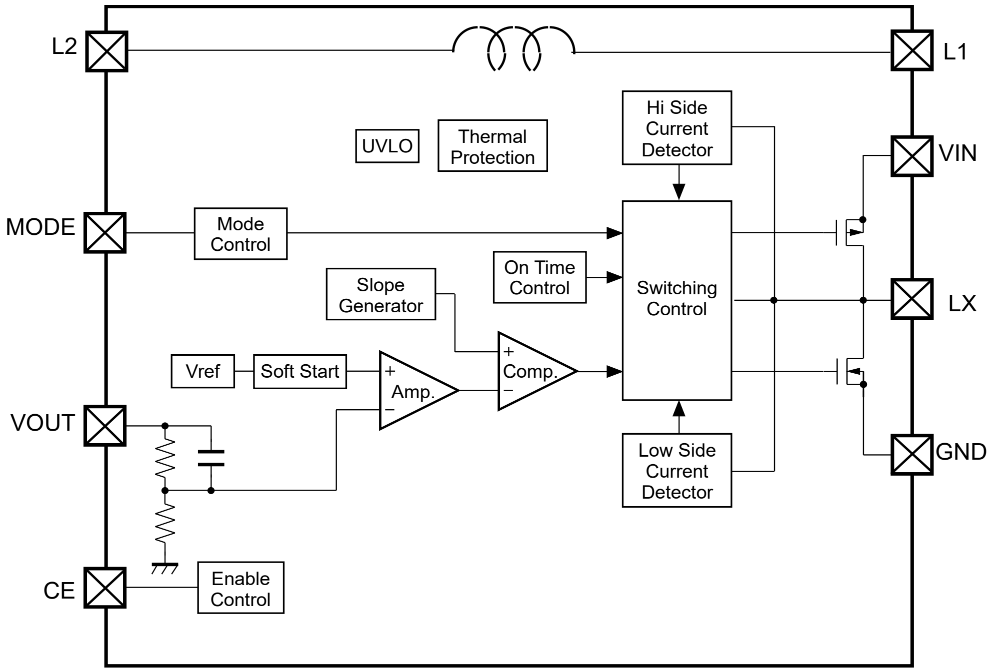
Adjustable Output Voltage Type : 00

$: Versions

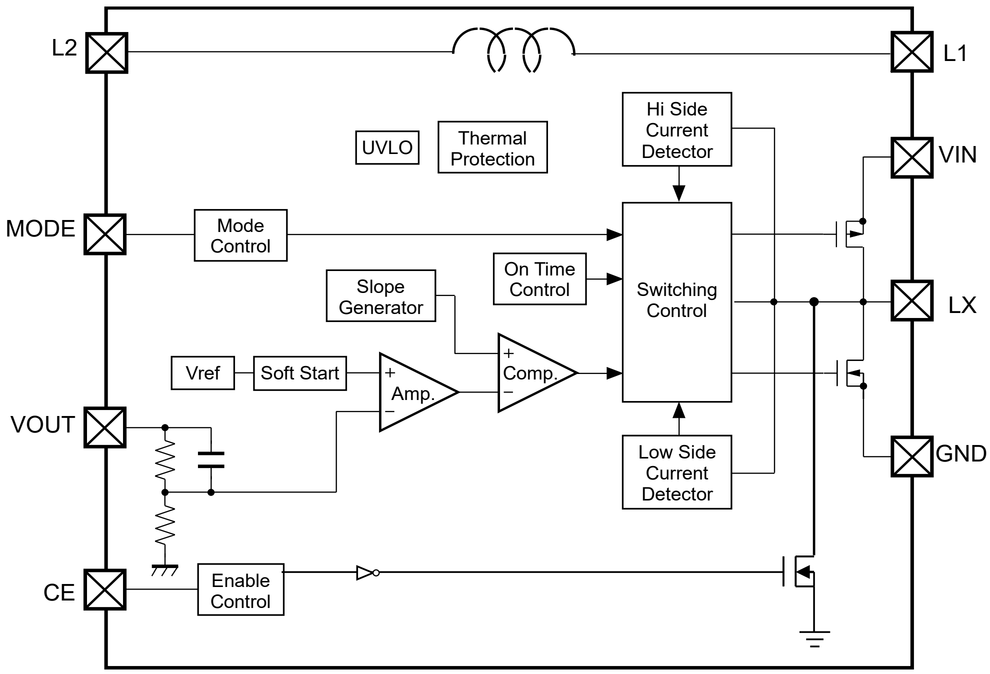
$	Output Voltage Type	Auto-discharge Function	V_{SET}
A	Fixed	No	0.6 V to 3.3 V
B		Yes	
C	Adjustable	No	0.6 V to 5.5 V
D		Yes	

BLOCK DIAGRAMS

RM590Lxx2A/B (Fixed Output Voltage Type)

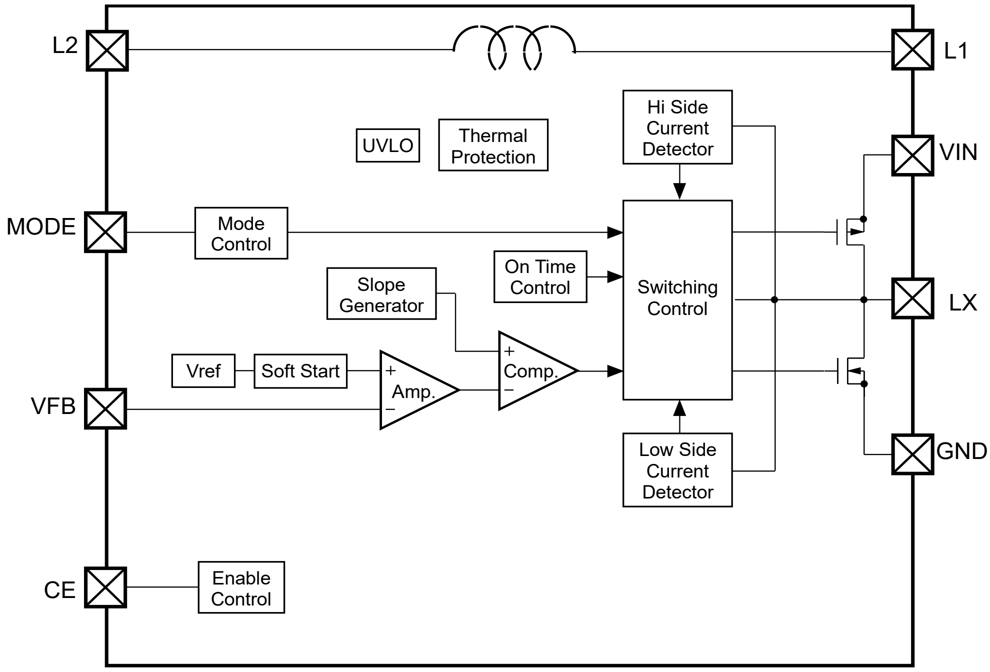


RM590Lxx2A Block Diagram

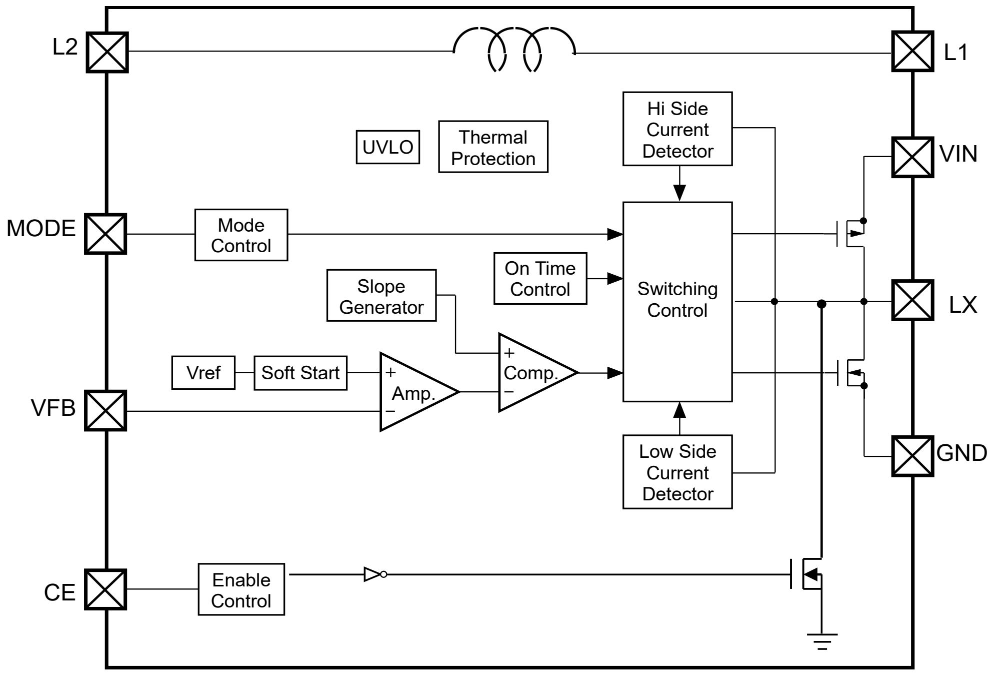


RM590Lxx2B Block Diagram

RM590L002C/D (Adjustable Output Voltage Type)

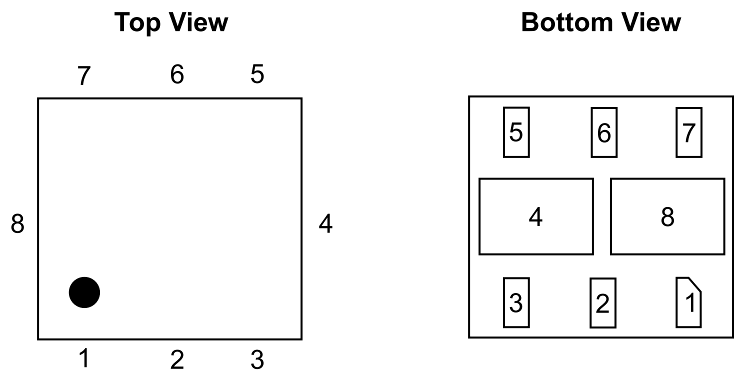


RM590L002C Block Diagram



RM590L002D Block Diagram

PIN DESCRIPTIONS



RM590L(QFN2220-8） Pin Configuration

RM590L (QFN2220-8) Pin Descriptions

Pin No.	Symbol	I/O	Description
1	VOUT/VFB	I	Output/Feedback Pin Fixed Output Voltage Type: Connect to V_{OUT} pin and L2 pin. Adjustable Output Voltage Type: Receives the feedback voltage from a Resistive divider connected across the output. Refer to “*Adjustable Output Voltage Setting*”
2	LX	O	Switch Node Connection to the Inductor. This pin connects to the drains of the internal Main and synchronous power MOSFET switches.
3	MODE	I	Mode Select Input. To select forced PWM, connect this pin to a voltage above designated "High". Connecting this pin to a voltage between 0 V and designated "Low" selects PWM/VFM automatic shift operation mode.
4	L1	I	Inductor Pin 1 (Input pin of inductor built-in.) Connect this pin to Lx pin.
5	VIN	I	Power Input Supply. Decouple this pin to GND with a capacitor.
6	CE	I	Forcing this pin below designated "Low" level shuts down the RM590L. In shutdown all functions are disabled except auto discharge function. (option)
7	GND	I	Ground Pin
8	L2	O	Inductor Pin 2 (This pin connects to built-in inductor) Connect a capacitor between this pin and GND.

ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Ratings	Unit
V_{IN}	Input Voltage	−0.3 to 6.5	V
V_{LX}	LX / L1 / L2 Pin Voltage	−0.3 to V_{IN} +0.3	V
V_{CE}	CE Pin Voltage	−0.3 to 6.5	V
V_{MODE}	MODE Pin Voltage	−0.3 to 6.5	V
V_{OUT}/V_{FB}	VOUT / VFB Pin Voltage	−0.3 to 6.5	V
I_{LX}	LX-Pin Output Current	1.6	A
P_D	Power Dissipation	Refer to Appendix "*POWER DISSIPATION*"	
Tj	Junction Temperature Range	−40 to 125	°C
Tstg	Storage Temperature Range	−55 to 125	°C

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause permanent damage and may degrade the lifetime and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings are not assured.

ELECTROSTATIC DISCHARGE (ESD) RATINGS

Symbol	Conditions	Ratings	Unit
V_{HBM}	HBM C = 100pF, R = 1.5kΩ	-750 / +2000	V
V_{CDM}	CDM	± 1000	V

ELECTROSTATIC DISCHARGE RATINGS

The electrostatic discharge test is done based on JESD47.
In the HBM method, ESD is applied using the power supply pin and GND pin as reference pins.

RECOMMENDED OPERATING CONDITIONS

Symbol	Item	Ratings	Unit
V_{IN}	Input Voltage	2.3 to 5.5	V
Ta	Operating Temperature Range	−40 to 85	°C

RECOMMENDED OPERATING CONDITIONS

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if they are used over such ratings by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

ELECTRICAL CHARACTERISTICS

The specifications surrounded by ☐ are guaranteed by design engineering at -40°C ≤ Ta ≤ 85°C.

RM590Lxx2A/B Electrical Characteristics (Ta = 25°C)

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_{OUT}	Output Voltage	V_{IN} = V_{CE} = 3.6 V (V_{SET} ≤ 2.6 V), V_{IN} = V_{CE} = V_{SET} + 1 V (V_{SET} > 2.6 V)	V_{SET} ≥ 1.2 V	x 0.985		x 1.015	V
			V_{SET} < 1.2 V	−0.018		+0.018	
f_{OSC}	Oscillator Frequency	V_{IN} = V_{CE} = 3.6 V, V_{SET} = 1.8 V, "Closed Loop Control"		4.8	6.0	7.2	MHz
I_{DD}	Supply Current	V_{IN} = V_{CE} = V_{OUT} = 3.6 V, V_{MODE} = 0 V			15		μA
$I_{STANDBY}$	Standby Current	V_{IN} = 5.5 V, V_{CE} = 0 V			0	5	μA
I_{CEH}	CE "High" Input Current	V_{IN} = V_{CE} = 5.5 V		−1	0	1	μA
I_{CEL}	CE "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = 0 V		−1	0	1	μA
I_{MODEH}	MODE "High" Input Current	V_{IN} = V_{MODE} = 5.5 V, V_{CE} = 0 V		−1	0	1	μA
I_{MODEL}	MODE "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = V_{MODE} = 0 V		−1	0	1	μA
I_{VOUTH}	V_{OUT} "High" Input Current	V_{IN} = V_{OUT} = 5.5 V, V_{CE} = 0 V		−1	0	1	μA
I_{VOUTL}	V_{OUT} "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = V_{OUT} = 0 V		−1	0	1	μA
R_{DISTR}	Auto-discharge MOSFET On-resistance (1)	V_{IN} = 3.6 V, V_{CE} = 0 V			40		Ω
$I_{LXLEAKH}$	LX "High" Leakage Current	V_{IN} = V_{LX} = 5.5 V, V_{CE} = 0 V		−1	0	5	μA
$I_{LXLEAKL}$	LX "Low" Leakage Current	V_{IN} = 5.5 V, V_{CE} = V_{LX} = 0 V		−5	0	1	μA
V_{CEH}	CE "High" Input Voltage	V_{IN} = 5.5 V		1.0			V
V_{CEL}	CE "Low" Input Voltage	V_{IN} = 2.3 V				0.4	V
V_{MODEH}	MODE "High" Input Voltage	V_{IN} = V_{CE} = 5.5 V		1.0			V
V_{MODEL}	MODE "Low" Input Voltage	V_{SET} ≤ 2.3 V, V_{IN} = V_{CE} = 2.3 V V_{SET} > 2.3 V, V_{IN} = V_{SET}				0.4	V
R_{ONP}	On-resistance of High Side MOSFET	V_{IN} = 3.6 V, I_{LX} = −100 mA			0.245		Ω
R_{ONN}	On-resistance of Low Side MOSFET	V_{IN} = 3.6 V, I_{LX} = −100 mA			0.225		Ω
Maxduty	Maximum Duty Cycle			100			%
t_{START}	Soft-start Time	V_{IN} = V_{CE} = 3.6 V (V_{SET} ≤ 2.6 V), V_{IN} = V_{CE} = V_{SET} + 1 V (V_{SET} > 2.6 V)			150	300	μs
I_{LXLIM}	LX Current Limit	V_{IN} = V_{CE} = 3.6 V (V_{SET} ≤ 2.6 V), V_{IN} = V_{CE} = V_{SET} + 1 V (V_{SET} > 2.6 V)		600	1000		mA
V_{UVLO1}	UVLO Threshold Voltage	V_{IN} = V_{CE}, Falling		1.85	2.00	2.20	V
V_{UVLO2}		V_{IN} = V_{CE}, Rising		1.90	2.05	2.25	V

All test items listed under Electrical Characteristics are done under the pulse load condition (Tj ≈ Ta = 25°C).

Test circuit is operated with “Open Loop Control” (GND = 0 V), unless otherwise specified.

(1) RM590Lxx2B only

The specifications surrounded by $\boxed{}$ are guaranteed by design engineering at -40°C ≤ Ta ≤ 85°C.

RM590L002C/D Electrical Characteristics (Ta = 25°C)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{FB}	Feedback Voltage	V_{IN} = V_{CE} = 3.6 V	$\boxed{0.591}$	0.600	$\boxed{0.609}$	V
f_{OSC}	Oscillator Frequency	V_{IN} = V_{CE} = 3.6 V, V_{SET} = 1.8 V, "Closed Loop Control"	$\boxed{4.8}$	6.0	$\boxed{7.2}$	MHz
I_{DD}	Supply Current	V_{IN} = V_{CE} = V_{OUT} = 3.6 V, V_{MODE} = 0 V		15		μA
$I_{STANDBY}$	Standby Current	V_{IN} = 5.5 V, V_{CE} = 0 V		0	$\boxed{5}$	μA
I_{CEH}	CE "High" Input Current	V_{IN} = V_{CE} = 5.5 V	$\boxed{-1}$	0	$\boxed{1}$	μA
I_{CEL}	CE "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = 0 V	$\boxed{-1}$	0	$\boxed{1}$	μA
I_{MODEH}	MODE "High" Input Current	V_{IN} = V_{MODE} = 5.5 V, V_{CE} = 0 V	$\boxed{-1}$	0	$\boxed{1}$	μA
I_{MODEL}	MODE "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = V_{MODE} = 0 V	$\boxed{-1}$	0	$\boxed{1}$	μA
I_{VOUTH}	V_{OUT} "High" Input Current	V_{IN} = V_{OUT} = 5.5 V, V_{CE} = 0 V	$\boxed{-1}$	0	$\boxed{1}$	μA
I_{VOUTL}	V_{OUT} "Low" Input Current	V_{IN} = 5.5 V, V_{CE} = V_{OUT} = 0 V	$\boxed{-1}$	0	$\boxed{1}$	μA
R_{DISTR}	Auto-discharge MOSFET On-resistance [1]	V_{IN} = 3.6 V, V_{CE} = 0 V		40		Ω
$I_{LXLEAKH}$	LX "High" Leakage Current	V_{IN} = V_{LX} = 5.5 V, V_{CE} = 0 V	$\boxed{-1}$	0	$\boxed{5}$	μA
$I_{LXLEAKL}$	LX "Low" Leakage Current	V_{IN} = 5.5 V, V_{CE} = V_{LX} = 0 V	$\boxed{-5}$	0	$\boxed{1}$	μA
V_{CEH}	CE "High" Input Voltage	V_{IN} = 5.5 V	$\boxed{1.0}$			V
V_{CEL}	CE "Low" Input Voltage	V_{IN} = 2.3 V			$\boxed{0.4}$	V
V_{MODEH}	MODE "High" Input Voltage	V_{IN} = V_{CE} = 5.5 V	$\boxed{1.0}$			V
V_{MODEL}	MODE "Low" Input Voltage	V_{SET} ≤ 2.3 V, V_{IN} = V_{CE} = 2.3 V V_{SET} > 2.3 V, V_{IN} = V_{SET}			$\boxed{0.4}$	V
R_{ONP}	On-resistance of High Side MOSFET	V_{IN} = 3.6 V, I_{LX} = −100 mA		0.245		Ω
R_{ONN}	On-resistance of Low Side MOSFET	V_{IN} = 3.6 V, I_{LX} = −100 mA		0.225		Ω
Maxduty	Maximum Duty Cycle		$\boxed{100}$			%
t_{START}	Soft-start Time	V_{IN} = V_{CE} = 3.6 V (V_{SET} ≤ 2.6 V), V_{IN} = V_{CE} = V_{SET} + 1 V (V_{SET} > 2.6 V)		150	$\boxed{300}$	μs
I_{LXLIM}	LX Current Limit	V_{IN} = V_{CE} = 3.6 V (V_{SET} ≤ 2.6 V), V_{IN} = V_{CE} = V_{SET} + 1 V (V_{SET} > 2.6 V)	$\boxed{600}$	1000		mA
V_{UVLO1}	UVLO Threshold Voltage	V_{IN} = V_{CE}, Falling	$\boxed{1.85}$	2.00	$\boxed{2.20}$	V
V_{UVLO2}		V_{IN} = V_{CE}, Rising	$\boxed{1.90}$	2.05	$\boxed{2.25}$	V

All test items listed under Electrical Characteristics are done under the pulse load condition (Tj ≈ Ta = 25°C).

Test circuit is operated with “Open Loop Control” (GND = 0 V), unless otherwise specified.

[1] RM590L002D only

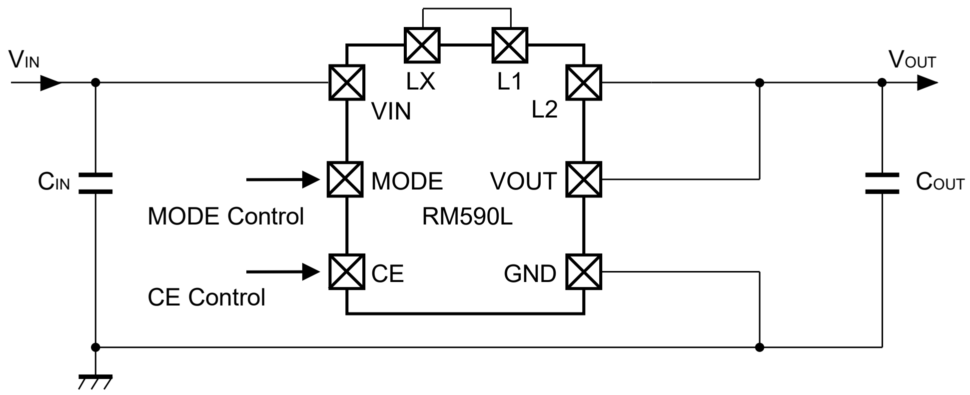
The specifications surrounded by ☐ are guaranteed by Design Engineering at −40°C ≤ Ta ≤ 85°C

RM590L series (Fixed Output Voltage Type) Product-specific Electrical Characteristics

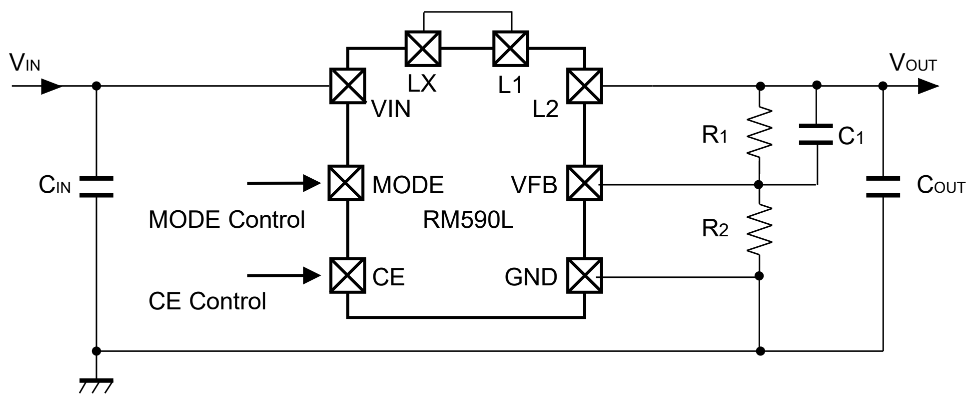
(Ta = 25°C)

Product Name	V_{OUT} [V]		
	Min.	V_{SET}	Max.
RM590L062x	0.582	0.600	0.618
RM590L072x	0.682	0.700	0.718
RM590L082x	0.782	0.800	0.818
RM590L092x	0.882	0.900	0.918
RM590L102x	0.982	1.000	1.018
RM590L102x5	1.032	1.050	1.068
RM590L112x	1.082	1.100	1.118
RM590L112x5	1.132	1.150	1.168
RM590L122x	1.182	1.200	1.218
RM590L132x	1.281	1.300	1.319
RM590L142x	1.379	1.400	1.421
RM590L152x	1.478	1.500	1.522
RM590L162x	1.576	1.600	1.624
RM590L172x	1.675	1.700	1.725
RM590L182x	1.773	1.800	1.827
RM590L192x	1.872	1.900	1.928
RM590L202x	1.970	2.000	2.030
RM590L212x	2.069	2.100	2.131
RM590L222x	2.167	2.200	2.233
RM590L232x	2.266	2.300	2.334
RM590L242x	2.364	2.400	2.436
RM590L252x	2.463	2.500	2.537
RM590L262x	2.561	2.600	2.639
RM590L272x	2.660	2.700	2.740
RM590L282x	2.758	2.800	2.842
RM590L292x	2.857	2.900	2.943
RM590L302x	2.955	3.000	3.045
RM590L312x	3.054	3.100	3.146
RM590L322x	3.152	3.200	3.248
RM590L332x	3.251	3.300	3.349

TYPICAL APPLICATION CIRCUIT



RM590Lxx2A/B (Fixed Output Voltage Type)



RM590L002C/D (Adjustable Output Voltage Type)

Recommended External Components

Symbol	Descriptions
C_{IN}	4.7 µF and more, Ceramic Capacitor
C_{OUT}	10 µF, Ceramic Capacitor

Precautions for the Selection of External Parts

- The RM590L has a built-in inductor with L=0.5μH and DCR=0.125Ω (TYP).

- Choose a low ESR ceramic capacitor. The capacitance of C_{IN} between VIN and GND should be more than or equal to 4.7 μF. The capacitance of a ceramic capacitor (C_{OUT}) should be 10 μF. Also, choose the capacitor with consideration for bias characteristics and input/output voltages.

OPERATION

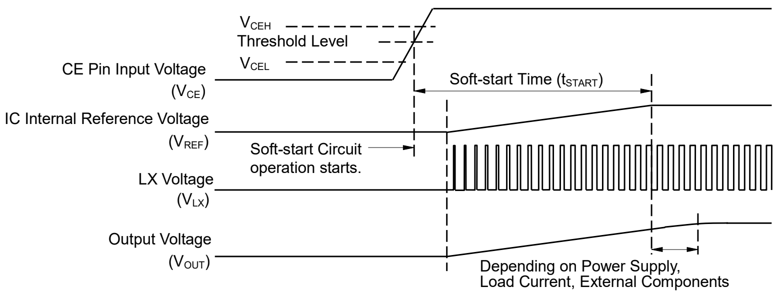
Chip Enable Function

Forcing above designated "High" voltage to CE pin, the RM590L becomes active. Forcing below designated "Low" voltage to CE pin shuts down the RM590L. In shutdown (Standby) condition, all functions are disabled except Auto Discharge function. (Option) With Auto-Discharge option, the MOSFET to discharge the output capacitor turns on and the output is pulled down to GND. Without Auto-Discharge option, the output becomes "Hi-Z". CE pin can accept input range voltage regardless of the input of VIN pin. If Chip Enable function is not necessary, tie CE pin to VIN pin or other designated "High" voltage node at start-up.

Soft-start Time

Starting-up with CE Pin

The IC starts to operate when the CE pin voltage (V_{CE}) exceeds the threshold voltage. The threshold voltage is preset between CE "High" input voltage (V_{CEH}) and CE "Low" input voltage (V_{CEL}).
After the start-of the start-up of the IC, soft-start circuit starts to operate. Then, after a certain period of time, the reference voltage (V_{REF}) in the IC gradually increases up to the specified value.
Notes: Soft start time (t_{START})[1] is not always equal to the turn-on speed of the step-down DC/DC module. Please note that the turn-on speed could be affected by the power supply capacity, the output current, the inductance value and the C_{OUT} value.



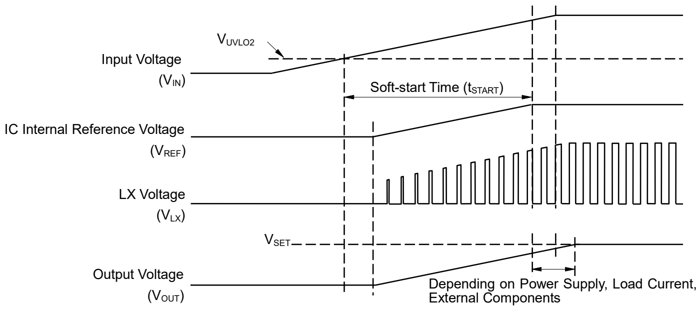
Timing Chart when Starting-up with CE Pin

(1) Soft-start time (t_{START}) indicates the duration until the reference voltage (V_{REF}) reaches the specified voltage after soft-start circuit's activation.

Starting-up with Power Supply

After the power-on, when V_{IN} exceeds the UVLO released voltage (V_{UVLO2}), the IC starts to operate. Then, soft-start circuit starts to operate and after a certain period of time, V_{REF} gradually increases up to the specified value.

Notes: Please note that the turn-on speed of V_{OUT} could be affected by the power supply capacity, the output current, the inductance value, the C_{OUT} value and the turn-on speed of V_{IN} determined by C_{IN}.



Timing Chart when Starting-up with Power Supply

Auto Discharge Function

When turned off, the Vout voltage drops rapidly to near 0V by discharging the charge stored in the output capacitor through the MOSFET connected between the LX and GND pins. The auto discharge function is enabled when the CE pin = "low" or the thermal shutdown detection or the UVLO detection. On-resistance of MOSFET is Typ. 40Ω. This function may be required to meet the required sequence for electronic components powered by this device.

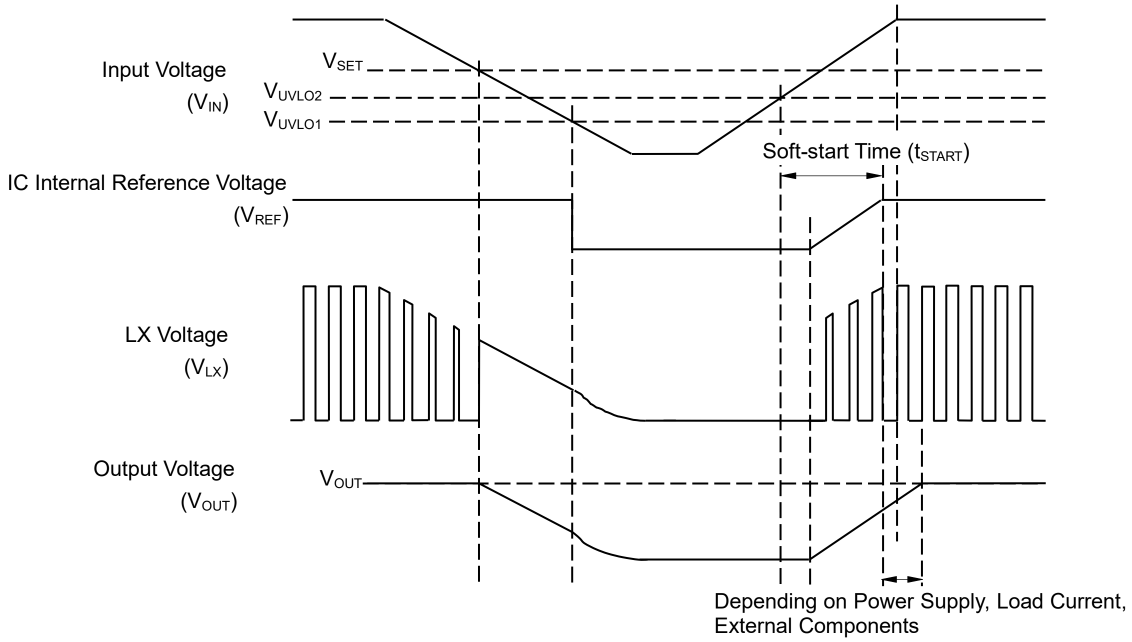
Undervoltage Lockout (UVLO) Circuit

If V_{IN} becomes lower than V_{SET}, the step-down DC/DC module stops the switching operation and ON duty becomes 100%, and then V_{OUT} gradually drops according to V_{IN}.

If the V_{IN} drops more and becomes lower than the UVLO detector threshold (V_{UVLO1}), the UVLO circuit starts to operate, V_{REF} stops, and High Side and Low Side built-in MOSFETs turn "OFF". As a result, V_{OUT} drops according to the C_{OUT} capacitance value and the load.

To restart the operation, V_{IN} needs to be higher than V_{UVLO2}. The timing chart below shows the voltage shifts of V_{REF}, V_{LX} and V_{OUT} when V_{IN} value is varied.

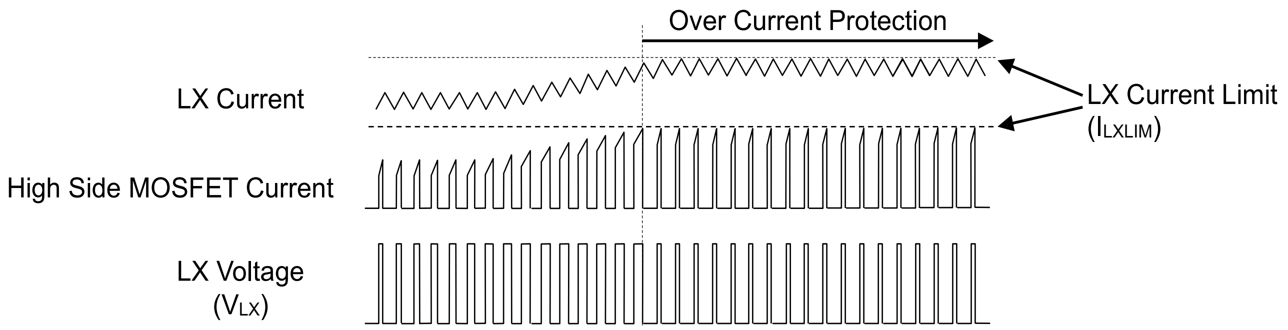
Notes: Falling edge (operating) and rising edge (releasing) waveforms of V_{OUT} could be affected by the initial voltage of C_{OUT} and the output current of V_{OUT}.



Timing Chart with Variations in Input Voltage (V_{IN})

Current limiting circuit

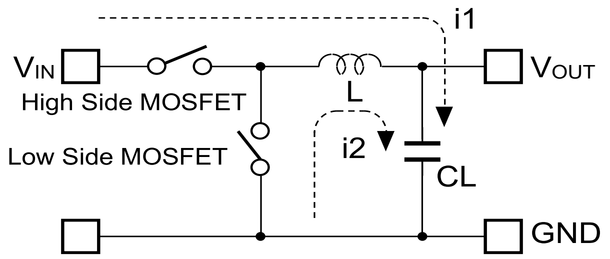
Current limit circuit supervises the inductor peak current (the peak current flowing through High Side MOSFET) in each switching cycle, and if the current exceeds the LX current limit (I_{LXLIM}), it turns off High Side MOSFET I_{LXLIM} of the RM590L is set to Typ.1.0 A.

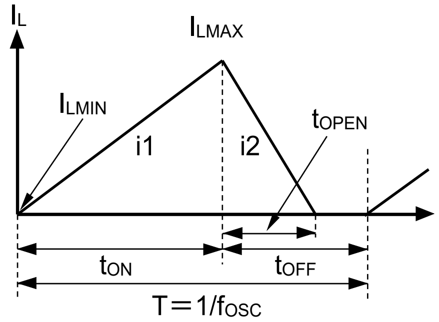


Over-Current Protection Operation

Operation of Step-down DC/DC module and Output Current

The step-down DC/DC module charges energy in the inductor when LX MOSFET turns “ON”, and discharges the energy from the inductor when LX MOSFET turns “OFF” and controls with less energy loss, so that a lower output voltage (V_{OUT}) than the input voltage (V_{IN}) can be obtained. The operation of the step-down DC/DC module is explained in the following figures.





Basic Circuit

Inductor Current (IL) flowing through Inductor (L)

Step1. High Side MOSFET turns “ON” and I_L (i1) flows, L is charged with energy. At this moment, i1 increases from the minimum inductor current (I_{LMIN}), which is 0 A, and reaches the maximum inductor current (I_{LMAX}) in proportion to the on-time period (t_{ON}) of High Side MOSFET.

Step2. When High Side MOSFET turns “OFF”, L tries to maintain I_L at I_{LMAX}, so L turns Low Side MOSFET “ON” and I_L (i2) flows into L.

Step3. i2 decreases gradually and reaches I_{LMIN} after the open-time period (t_{OPEN}) of Low Side MOSFET, and then Low Side MOSFET turns “OFF”. This is called discontinuous current mode.
As the output current (I_{OUT}) increases, the off-time period (t_{OFF}) of High Side MOSFET runs out before I_L reaches I_{LMIN}. The next cycle starts, and High Side MOSFET turns “ON” and Low Side MOSFET turns “OFF”, which means I_L starts increasing from I_{LMIN}. This is called continuous current mode.

In PWM mode, V_{OUT} is maintained by controlling t_{ON}. The oscillator frequency (f_{OSC}) is maintained constant during PWM mode.
When the step-down DC/DC operation is constant, I_{LMIN} and I_{LMAX} during t_{ON} of High Side MOSFET would be same as during t_{OFF} of High Side MOSFET. The current differential between I_{LMAX} and I_{LMIN} is described as ΔI, as the following equation (1).

$\Delta I = I_{LMAX} - I_{LMIN} = V_{OUT} \times t_{OPEN} / 0.5 = (V_{IN} - V_{OUT}) \times t_{ON} / 0.5$ ·· (1)

The above equation is predicated on the following requirements.

$T = 1 / f_{OSC} = t_{ON} + t_{OFF}$

$\text{duty}\ (\%) = t_{ON} / T \times 100 = t_{ON} \times f_{OSC} \times 100$

$t_{OPEN} \leq t_{OFF}$

In Equation 1, “$V_{OUT} \times t_{OPEN} / 0.5$” shows the amount of current change in "OFF" state. Also, “$(V_{IN} - V_{OUT}) \times t_{ON}$ / L0.5” shows the amount of current change at "ON" state.

Discontinuous Mode and Continuous Mode

As illustrated in Figure A., when I_{OUT} is relatively small, $t_{OPEN} < t_{OFF}$. In this case, the energy charged into L during t_{ON} will be completely discharged during t_{OFF}, as a result, $I_{LMIN} = 0$. This is called discontinuous mode. When I_{OUT} is gradually increased, eventually $t_{OPEN} = t_{OFF}$ and when I_{OUT} is increased further, eventually $I_{LMIN} > 0$ as illustrated in Figure B. This is called continuous mode.

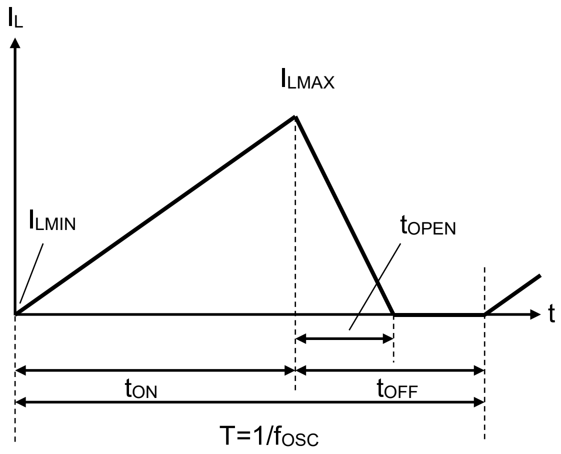


Figure A. Discontinuous Mode

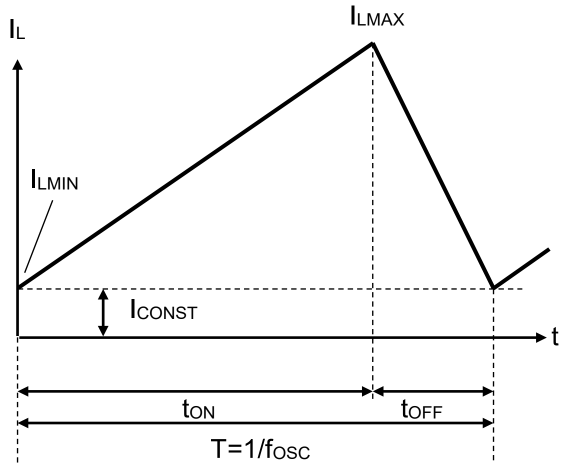


Figure B. Continuous Mode

In the continuous mode, the solution of Equation (1) is described as t_{ONC}.

$t_{ONC} = T \times V_{OUT} / V_{IN}$ ··························· (2)

When $t_{ON} < t_{ONC}$, it is discontinuous mode, and when $t_{ON} = t_{ONC}$, it is continuous mode.

Forced PWM Mode and VFM Mode

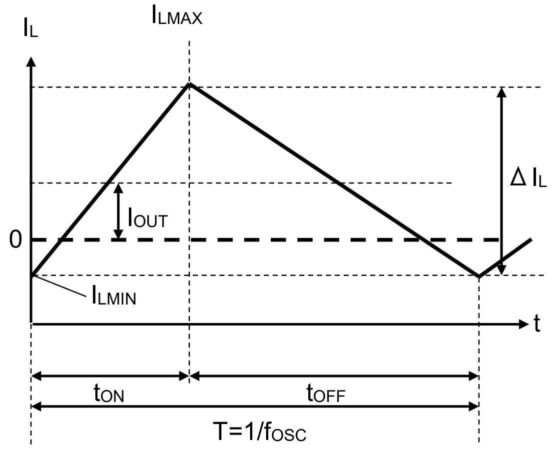
Output voltage controlling method is selectable between a forced PWM control type and a PWM/VFM auto-switching control type, and can be set by the MODE pin. The forced PWM control switches at fixed frequency rate in order to reduce noise in low output current. The PWM/VFM auto-switching control automatically switches from PWM mode to VFM mode in order to achieve high efficiency in low output current.

Forced PWM Mode

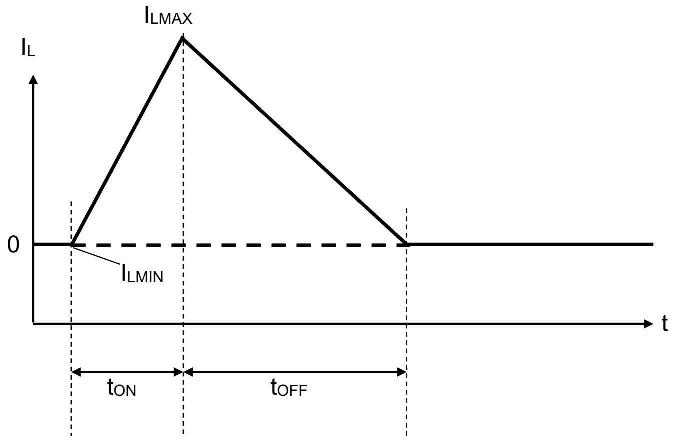
By setting the MODE pin to "High", the IC switches the frequency at the fixed rate to reduce noise even when the output load is light. Therefore, when I_{OUT} is $\Delta I_L/2$ or less, I_{LMIN} becomes less than “0”. That is, the accumulated electricity in CL is discharged through the IC side while I_L is increasing from I_{LMIN} to “0” during t_{ON}, and also while I_L is decreasing from “0” to I_{LMIN} during t_{OFF}.

VFM Mode

By setting the MODE pin to "Low", in low output current, the IC automatically switches into VFM mode in order to achieve high efficiency. In VFM mode, t_{ON} is determined depending on V_{IN} and V_{OUT}.



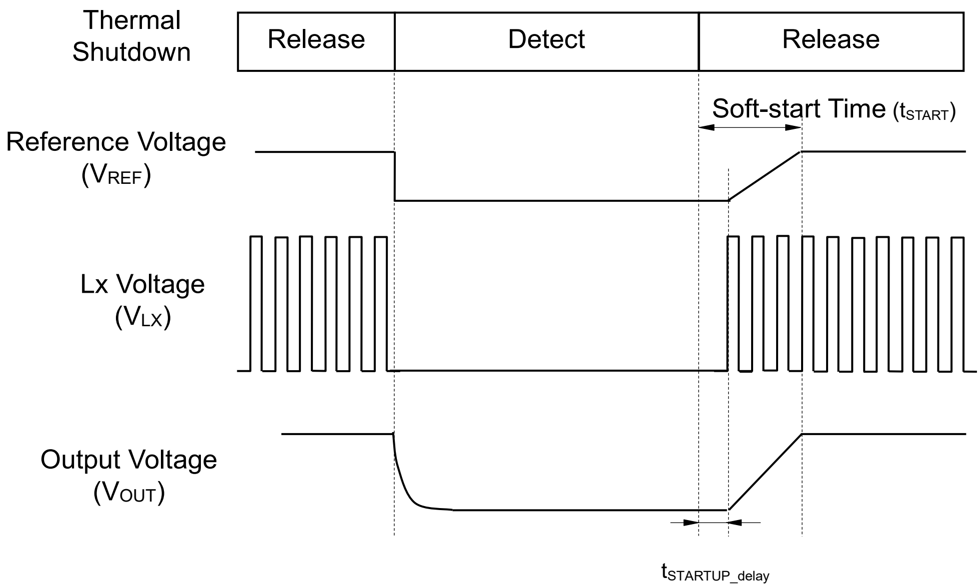
Forced PWM Mode



VFM Mode

Thermal Shutdown Function

When the junction temperature exceeds the thermal shutdown detection temperature (Typ. 140°C), this IC cuts off the output and suppresses the self-heating. When the junction temperature falls below the thermal shutdown release temperature (Typ. 100°C), this IC will restart with the soft start operation.

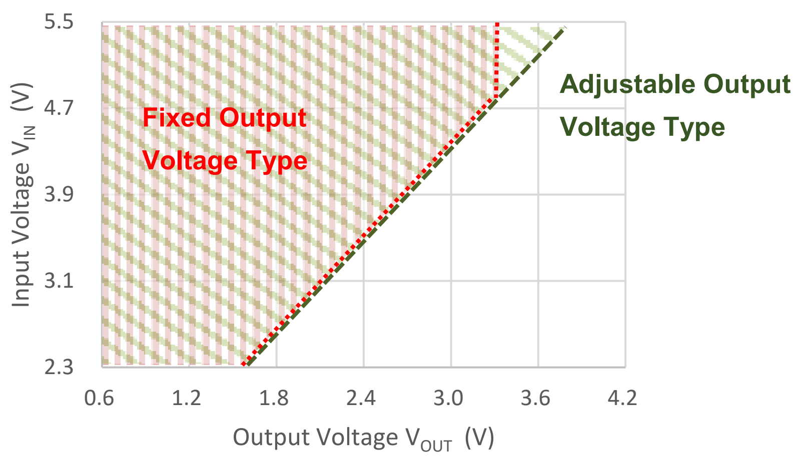


TECHNICAL NOTES

The performance of a power source circuit using this device is highly dependent on a peripheral circuit. A peripheral component or the device mounted on PCB should not exceed its rated voltage, rated current or rated power. When designing a peripheral circuit, please be fully aware of the following points.

- Set the external components as close as possible to the IC and minimize the wiring between the components and the IC. Especially, place a capacitor (C_{IN}) as close as possible to the VIN pin and GND.
- Ensure the VIN and GND lines are sufficiently robust. If their impedance is too high, noise pickup or unstable operation may result.
- A large switching current flows through the VIN line, GND line, VOUT line, inductor, LX, L1 and L2. Make the wirings short and wide.
- For any setting type of output voltage, the input/output voltage ratio must meet the following requirement to achieve a stable VFM mode at light load when the MODE pin is "Low" (at PWM/VFM Auto Switching) :
  $V_{OUT} / V_{IN} < 0.7$

V_{MODE} = "Low", PWM / VFM Auto Switching



Available Voltage Area with Stable VFM Mode

- The thermal shutdown function is to prevent smoke and ignition of the IC, not to ensure the reliability of the IC or to keep it below the absolute maximum rating. In addition, it is not effective against heat generated when the IC is not operating normally, such as latch-up and overvoltage application.
- Do not design with depending on the thermal shutdown function of this IC as the system protection. The thermal shutdown function is designed for this IC.
- ESD Control
  Take appropriate precautions when handling this product or PCB included this product.
  Ex.
  - Use of an antistatic wrist band
  - Use of an ionizer

APPLICATION INFORMATION

Adjustable Output Voltage Setting (RM590L002C/D)

By connecting divider resistors (R1, R2) to the VFB pin, the set output voltage (V_{SET}) can be set using the following equation.

$V_{SET} = V_{FB} \times (R1 + R2) / R2$

The reference voltage (V_{FB}) of this IC is set to 0.6 V, and the accuracy of V_{FB} and the output voltage setting range are as follows.

V_{SET}: 0.6V ≤ V_{SET} ≤ 5.5 V

V_{FB} : 0.6 V ± 9mV

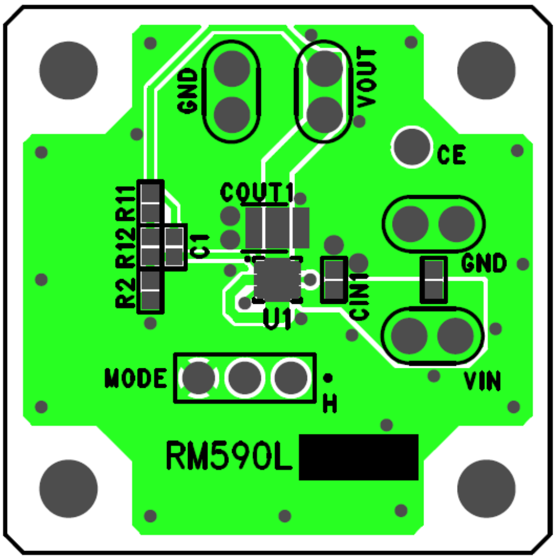
Refer to the following table for the recommended values for R1, R2 and C1.

Set Output Voltage (V_{SET}) vs. R1 / R2 / C1 (Adjustable Output Voltage Type)

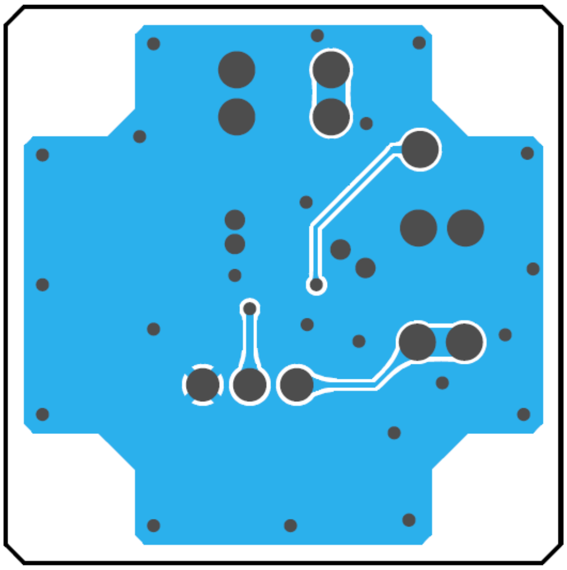
V_{SET} [V]	R1 [kΩ]	R2 [kΩ]	C1 [pF]
0.6	0	220	Open
0.6 < V_{SET} ≤ 0.9	R1 = (V_{SET} / V_{FB} -1) x R2	220	47
0.9 < V_{SET} ≤ 1.8		220	33
1.8 < V_{SET} ≤ 2.1		150	10
2.1 < V_{SET} ≤ 2.4		100	10
2.4 < V_{SET} ≤ 2.7		68	10
2.7 < V_{SET} ≤ 3.0		47	10
3.0 < V_{SET} ≤ V_{IN}		47	6.8

PCB Layout

RM590L (QFN2220-8) Board Diagram



Top Layer



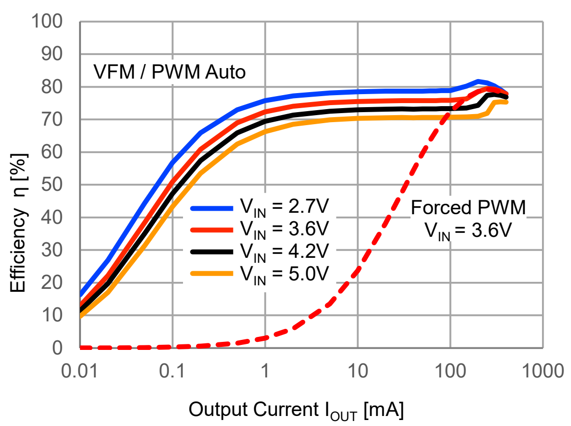
Bottom Layer

TYPICAL CHARACTERISTICS

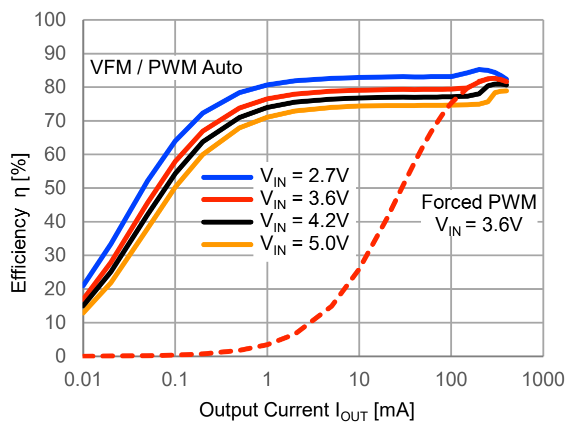
Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

1) Efficiency vs. Output Current

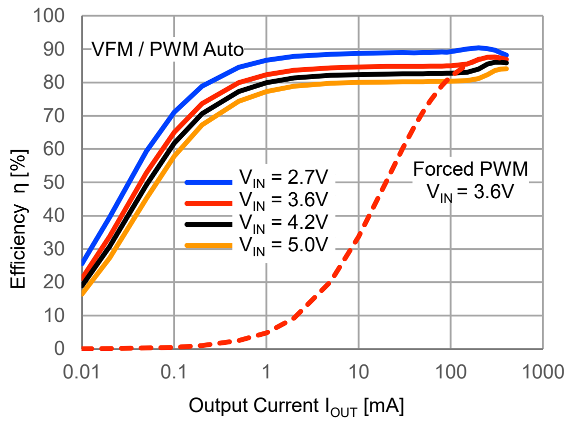
V_{OUT}=0.9V



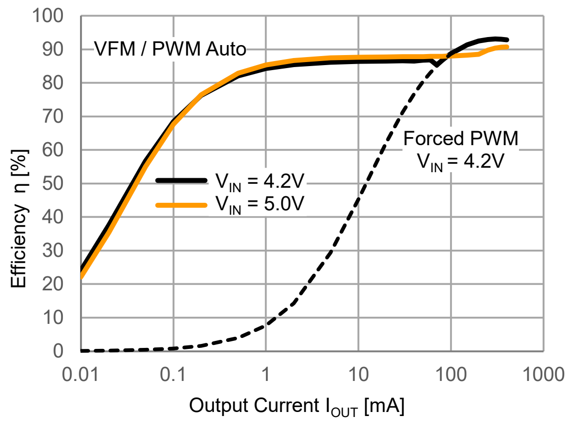
V_{OUT}=1.2V



V_{OUT}=1.8V

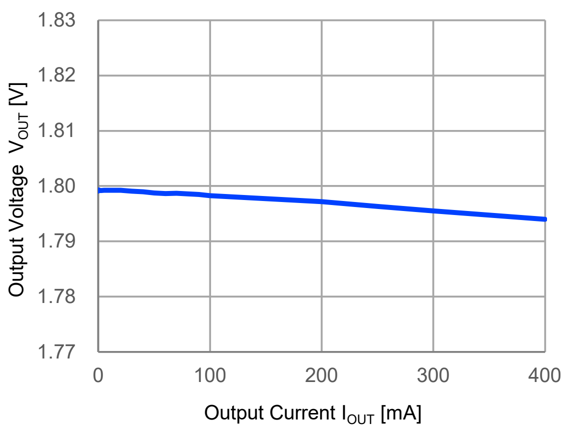


V_{OUT}=3.3V

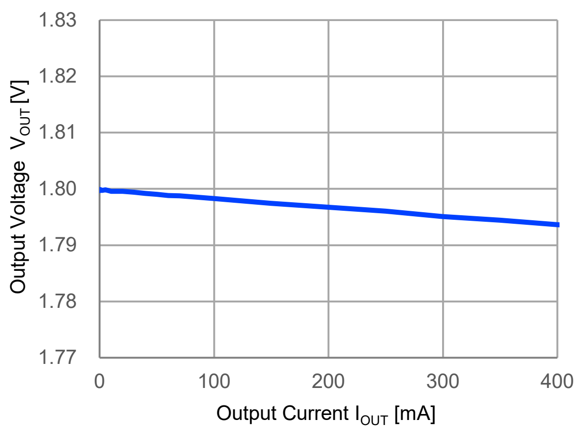


2) Output Voltage vs. Output Current

V_{IN}=3.6V, V_{OUT}=1.8V
MODE = "H" Forced PWM Mode

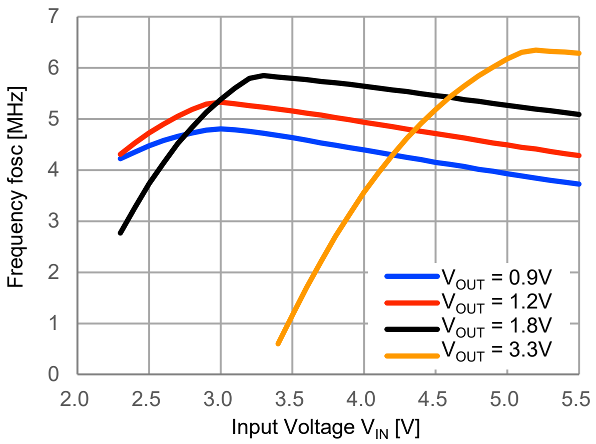


V_{IN}=3.6V, V_{OUT}=1.8V
MODE = "L" PWM/VFM Auto Switching

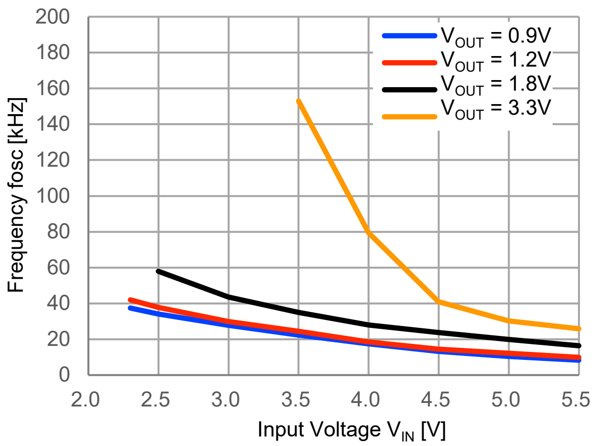


3) **Oscillator Frequency vs. Input Voltage**

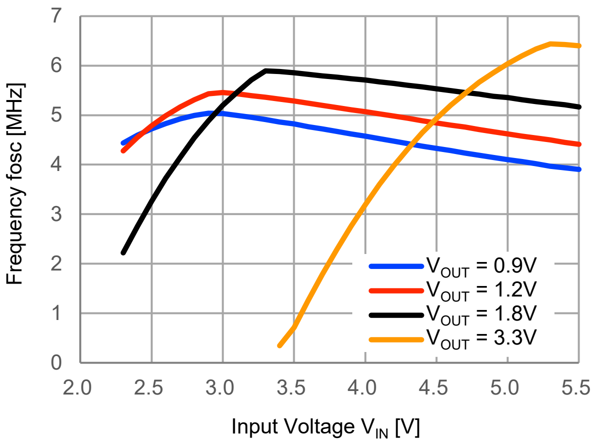
I_{OUT}=1mA
MODE = "H" Forced PWM Mode



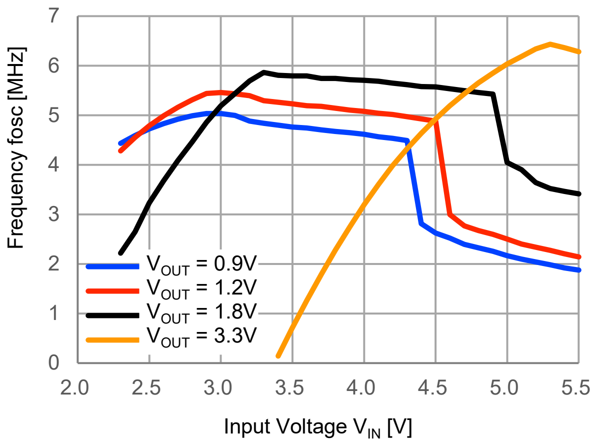
I_{OUT}=1mA
MODE = "L" PWM/VFM Auto Switching



I_{OUT}=200mA
MODE = "H" Forced PWM Mode

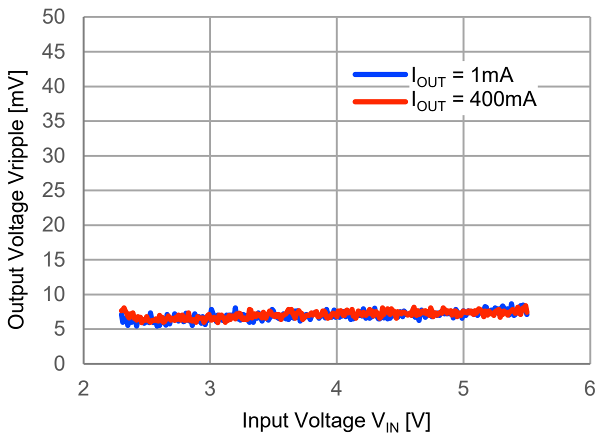


I_{OUT}=200mA
MODE = "L" PWM/VFM Auto Switching

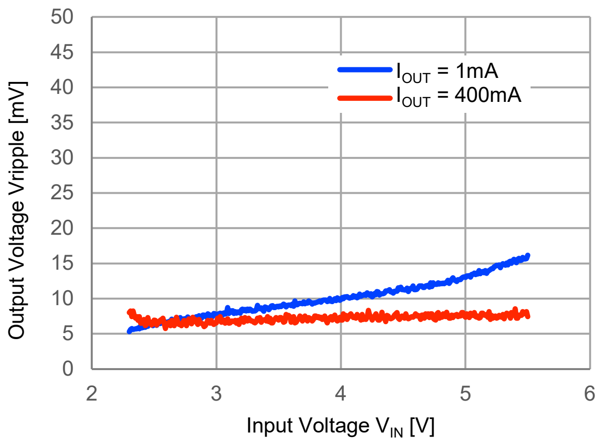


4) **Ripple Voltage vs. Input Voltage**

V_{IN}=3.6V, V_{OUT}=1.8V
MODE = "H" Forced PWM Mode

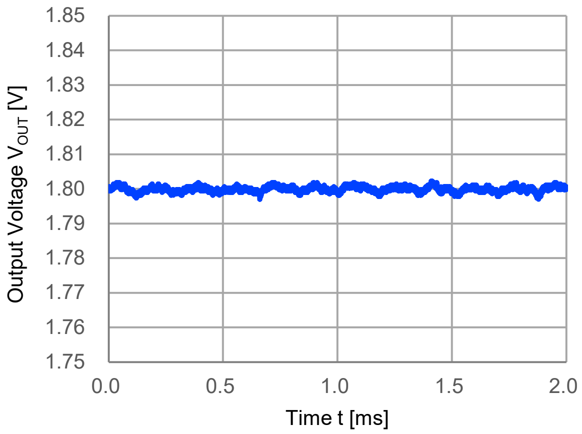


V_{IN}=3.6V, V_{OUT}=1.8V
MODE = "L" PWM/VFM Auto Switching

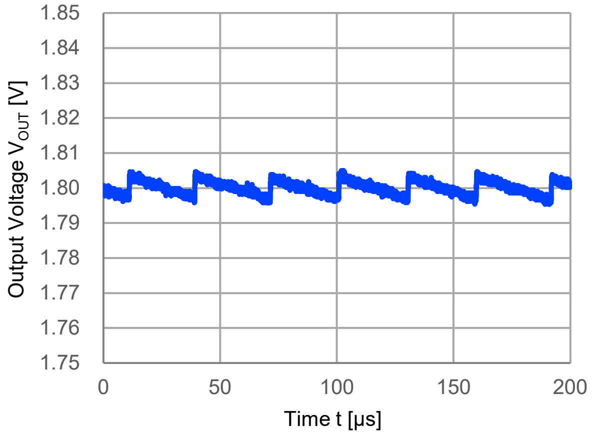


5) **Output Voltage Waveform**

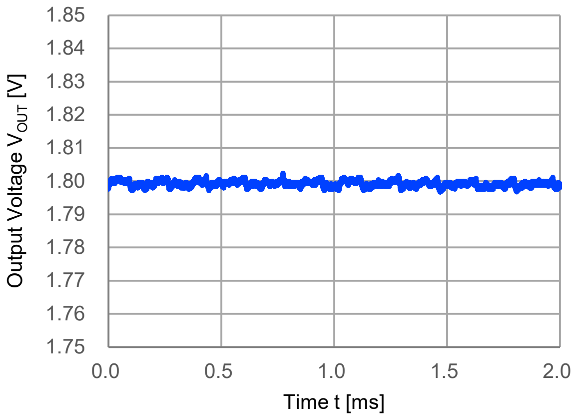
V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=1mA
MODE = "H" Forced PWM Mode



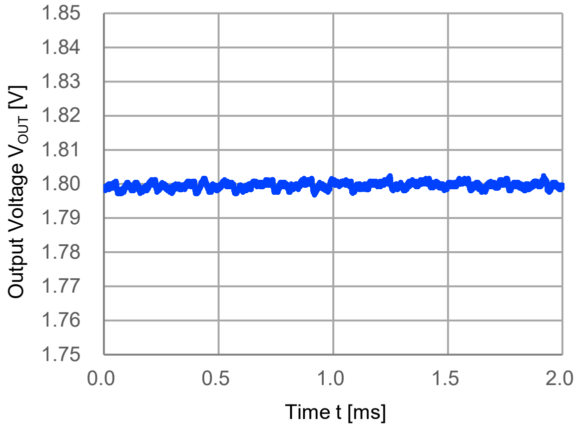
V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=1mA
MODE = "L" PWM/VFM Auto Switching



V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=400mA
MODE = "H" Forced PWM Mode

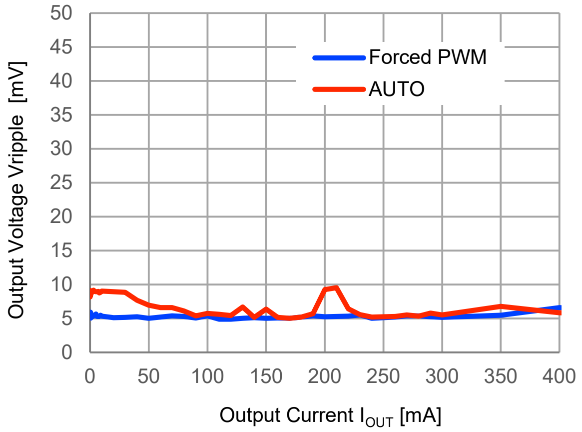


V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=400mA
MODE = "L" PWM/VFM Auto Switching



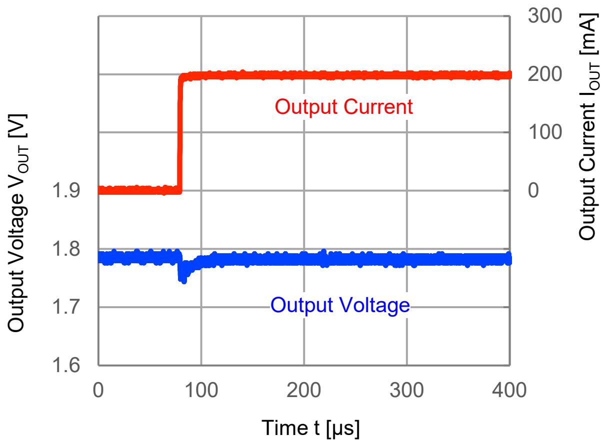
6) **Ripple Voltage vs. Output Current**

V_{IN}=3.6V, V_{OUT}=1.8V
MODE = "L" PWM/VFM Auto Switching, MODE = "H" Forced PWM Mode

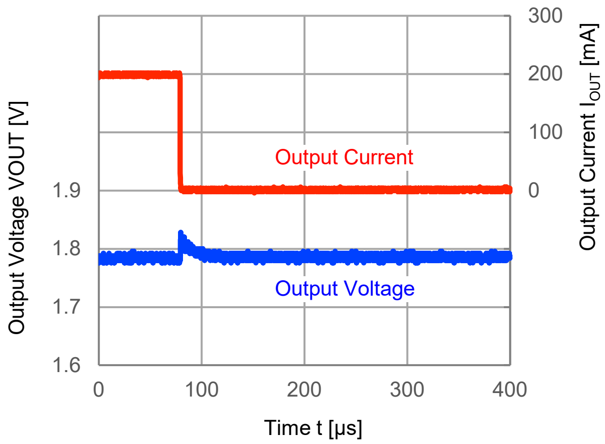


7) **Load Transient Response Waveform**

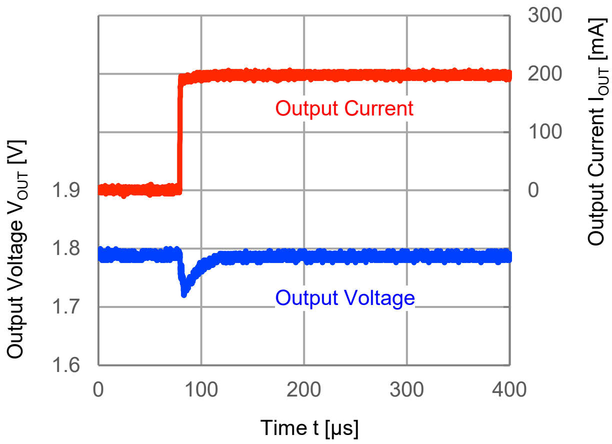
V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=1mA->200mA
MODE = "H" Forced PWM Mode



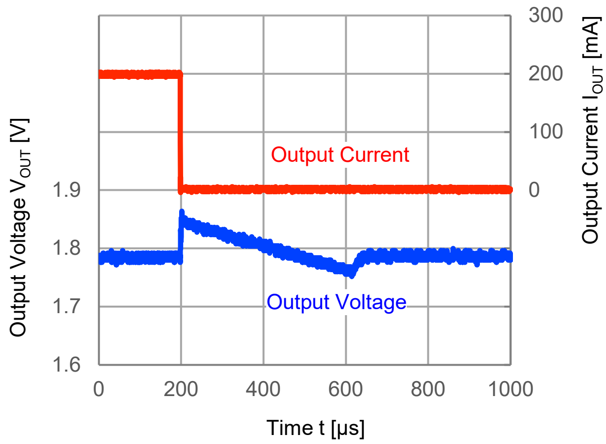
V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=200mA->1mA
MODE = "H" Forced PWM Mode



V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=1mA->200mA
MODE = "L" PWM/VFM Auto Switching

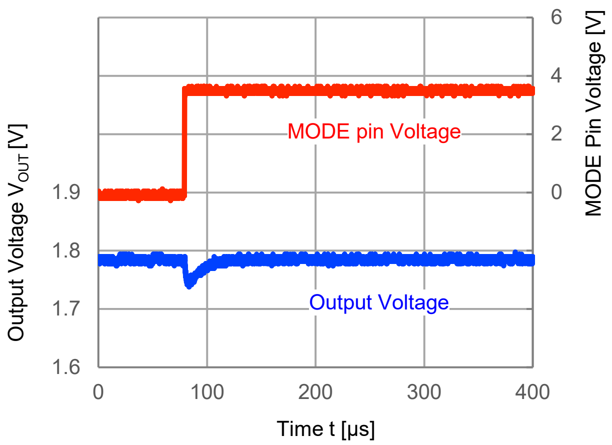


V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=200mA->1mA
MODE = "L" PWM/VFM Auto Switching

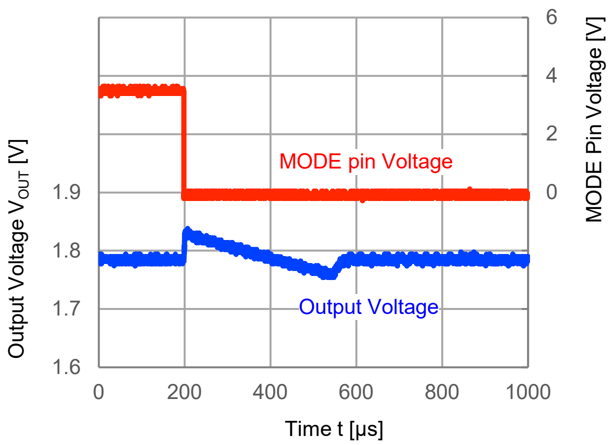


8) **Mode Switching Waveform**

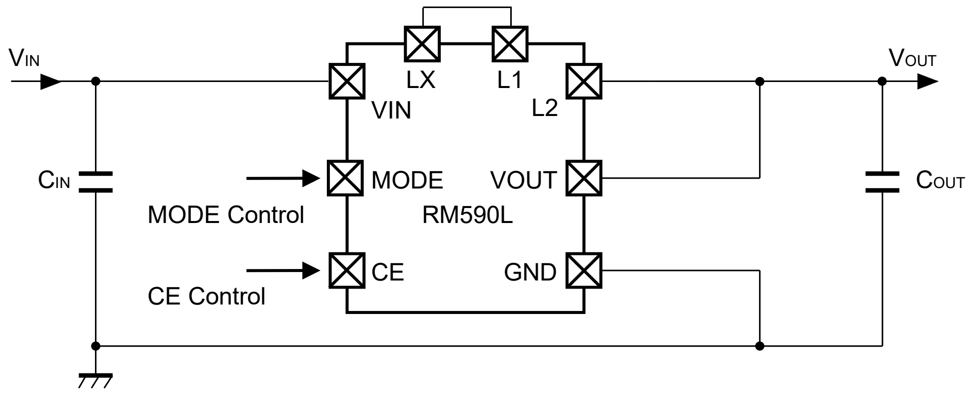
V_{IN}=3.6V, V_{OUT}=1.8V, I_{OUT}=1mA
MODE = "L" -> "H"



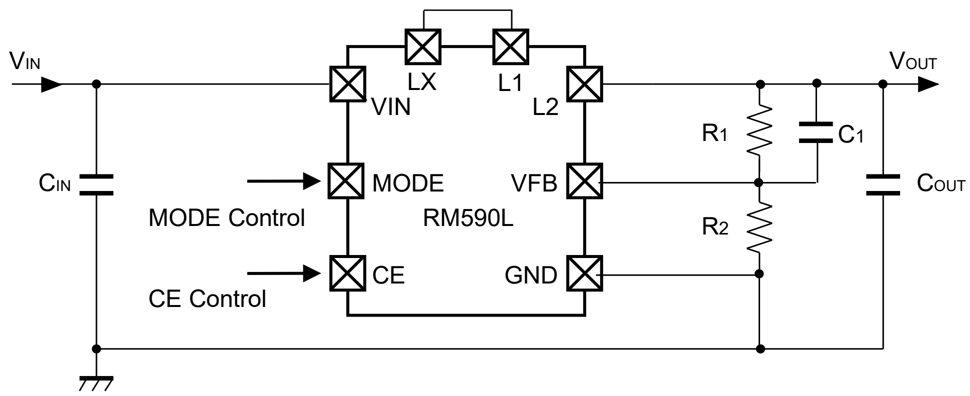
MODE = "H" -> "L"



Test Circuit



RM590Lxx2A/B (Fixed Output Voltage Type)



RM590L002C/D (Adjustable Output Voltage Type)

Components list for our evaluation

Symbol	Specification	Maximum Ratings	Model
C_{IN}	4.7µF	6.3V	C1005X5R0J475M050BC
C_{OUT}	10uF	6.3V	GRM155R60J106ME44D

PD-QFN2220-8(85125)-JE-A

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following measurement conditions are based on JEDEC STD. 51.

Measurement Conditions

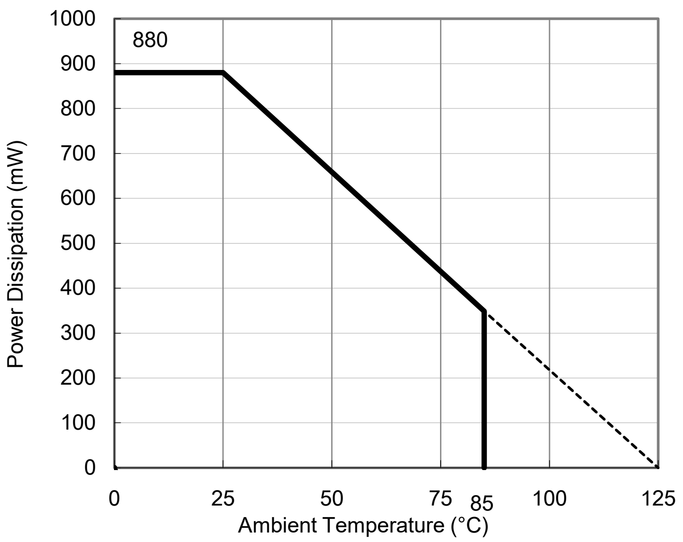
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 1.6 mm
Copper Ratio	Outer Layer (First Layer): More than 90% of 74.2 mm Square Inner Layers (Second and Third Layers): Approx. 100% of 74.2 mm Square Outer Layer (Fourth Layer): More than 90% of 74.2 mm Square
Through-holes	ϕ 0.3 mm × 4 pcs

Measurement Result (Ta = 25°C, Tjmax = 125°C)

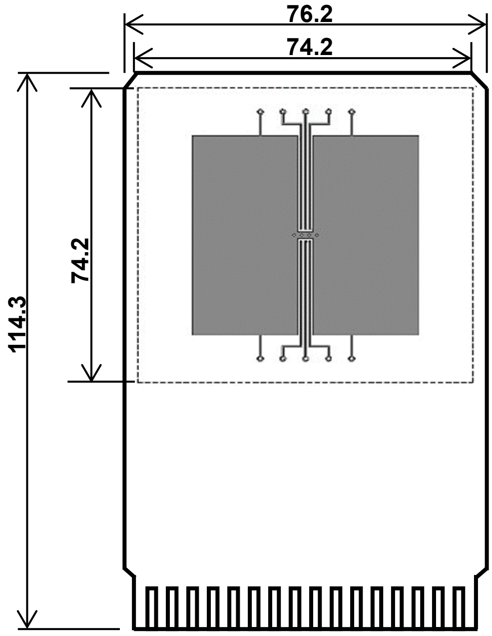
Item	Measurement Result
Power Dissipation	880 mW
Thermal Resistance (θja)	θja = 113°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 55°C/W

θja: Junction-to-Ambient Thermal Resistance

ψjt: Junction-to-Top Thermal Characterization Parameter

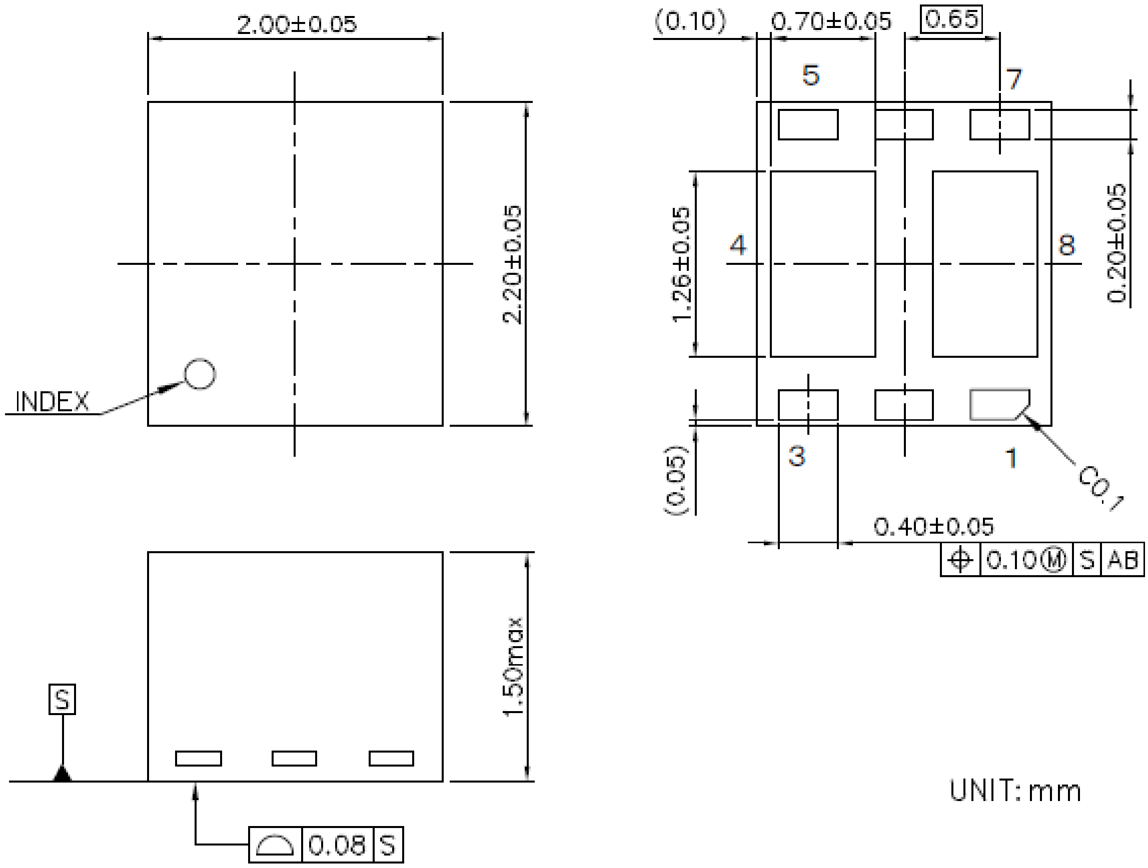


Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

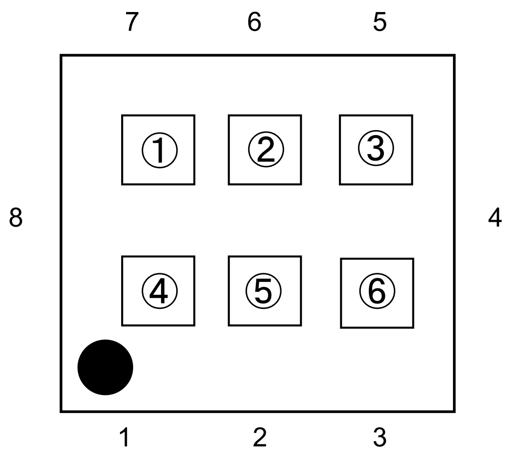
DM-QFN2220-8-JE-A



QFN2220-8 Package Dimensions

①②③④: Product Code ··· Refer to *Part Marking List*

⑤⑥: Lot Number ··· Alphanumeric Serial Number



QFN2220-8 Part Markings

NOTICE
There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

MK-RM590L-JAEA-A

RM590Lxx2A / RM590Lxx2B (Fixed Output Voltage Type) Part Marking List

Product Name	①②③④	V_{OUT}	Product Name	①②③④	V_{OUT}
RM590L062A	101A	0.6 V	RM590L062B	301B	0.6 V
RM590L072A	102A	0.7 V	RM590L072B	302B	0.7 V
RM590L082A	103A	0.8 V	RM590L082B	303B	0.8 V
RM590L092A	104A	0.9 V	RM590L092B	304B	0.9 V
RM590L102A	105A	1.0 V	RM590L102B	305B	1.0 V
RM590L102A5	115A	1.05 V	RM590L102B5	306B	1.05 V
RM590L112A	106A	1.1 V	RM590L112B	307B	1.1 V
RM590L112A5	107A	1.15 V	RM590L112B5	308B	1.15 V
RM590L122A	108A	1.2 V	RM590L122B	309B	1.2 V
RM590L132A	109A	1.3 V	RM590L132B	310B	1.3 V
RM590L142A	110A	1.4 V	RM590L142B	311B	1.4 V
RM590L152A	111A	1.5 V	RM590L152B	312B	1.5 V
RM590L162A	112A	1.6 V	RM590L162B	313B	1.6 V
RM590L172A	113A	1.7 V	RM590L172B	314B	1.7 V
RM590L182A	114A	1.8 V	RM590L182B	315B	1.8 V
RM590L192A	201A	1.9 V	RM590L192B	401B	1.9 V
RM590L202A	202A	2.0 V	RM590L202B	402B	2.0 V
RM590L212A	203A	2.1 V	RM590L212B	403B	2.1 V
RM590L222A	204A	2.2 V	RM590L222B	404B	2.2 V
RM590L232A	205A	2.3 V	RM590L232B	405B	2.3 V
RM590L242A	206A	2.4 V	RM590L242B	406B	2.4 V
RM590L252A	207A	2.5 V	RM590L252B	407B	2.5 V
RM590L262A	208A	2.6 V	RM590L262B	408B	2.6 V
RM590L272A	209A	2.7 V	RM590L272B	409B	2.7 V
RM590L282A	210A	2.8 V	RM590L282B	410B	2.8 V
RM590L292A	211A	2.9 V	RM590L292B	411B	2.9 V
RM590L302A	212A	3.0 V	RM590L302B	412B	3.0 V
RM590L312A	213A	3.1 V	RM590L312B	413B	3.1 V
RM590L322A	214A	3.2 V	RM590L322B	414B	3.2 V
RM590L332A	215A	3.3 V	RM590L332B	415B	3.3 V

RM590L002C / RM590L002D (Adjustable Output Voltage Type) Part Marking List

Product Name	① ② ③ ④	Product Name	① ② ③ ④
RM590L002C	5 0 1 C	RM590L002D	6 0 1 D

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