

## 3D Step-Down DC-DC Power Delivery SoC

### FEATURES

- Fully Integrated Switching Power SoC Including Controller, Power Switches, Inductor and Capacitor Filters
- 3.8V - 32V Wide Input Voltage Range
- Continuous Output Load Current
  - 0.5A in GRM2905
- Output Voltage Options: 9.0V, 5.0V, 3.3V, 2.5V, 1.8V, 1.2V
- Precision Output Voltage Accuracy of  $\pm 1\%$
- Low Output Ripples
- Support Low Drop-Out Mode - LDO Operation
- 20uA Low Quiescent Current in Light Load Condition
- 4ms Built-in Soft Start Time
- High efficiency with no heatsink required
- Wide Operation Temperature Range of  $-45^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Output Over Voltage Protection, Over Current Protection and Thermal Shutdown Protection
- Super Ease-of-Use in TO-220 and TO-263 Package
- Pin-out and Device Case Compatible with LM78XX LDO
- Low EMI
- Lead free, halogen free and RoHS compliant

### APPLICATIONS

- Industrial Control Systems
- Battery-Powered Equipment
- Renewable Energy Systems
- Automotive Electronics
- LM78XX Linear Power Regulator Replacement with High Efficiency

### GENERAL DESCRIPTION

The GRM2905 are fully integrated Buck power conversion sub-system SoC devices including PWM controllers, power switches, power inductors and input and output voltage capacitor filters. The power delivery SoC device is designed in a proprietary 3D power integration structure in the commonly used TO220 and TO263 packages featuring both high density and high efficiency. The input voltage capacitor filter power switches, power inductor and output voltage capacitor filter are crafted in a small loop for switching power current to lower EMI impacts.

The GRM2905 control scheme adopts peak current mode control with optimize compensation network to achieve fast voltage loop response. It supports the Pulse Skipping Modulation (PSM) at light load with typical 20uA ultra-low Quiescent current. When the input voltage drops close to the output voltage, the device changes from switching operation to low drop-out leaner regulation.

The GRM2905 offers output over-voltage protection, cycle-by-cycle peak current limit, and thermal shutdown protection. The device which is available in TO-220 and TO-263 package has low thermal resistance and does not require any heatsink.

### TYPICAL APPLICATION CIRCUIT

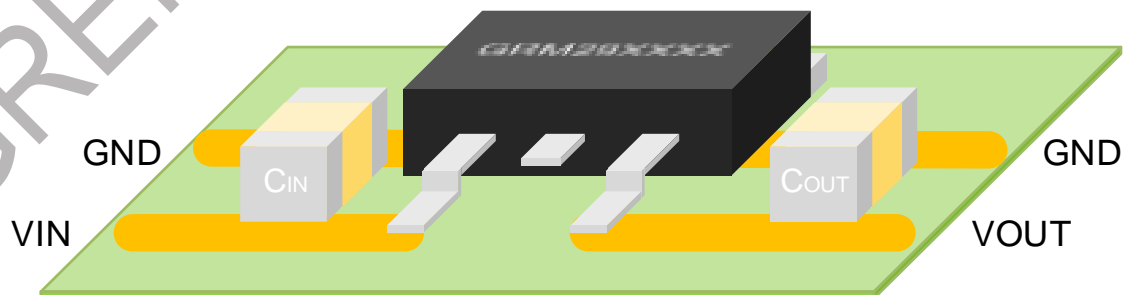


Figure 1. Typical Application Circuit

**ELECTRICAL CHARACTERISTICS**

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C \sim 125^{\circ}C$ , typical value is tested under  $25^{\circ}C$ .

**Table 1.**

Symbol	Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
<b>Power Supply and Output</b>						
$V_{IN}$	Operating input voltage		3.8		32	V
$V_{IN\_UVLO}$	Input UVLO Hysteresis	$V_{IN}$ rising		3.5 420	3.7	V mV
$I_{SD}$	Shutdown current	EN=0, No load, $V_{IN}=12V$		1	3	uA
$I_Q$	Quiescent current	EN=floating, No load, No switching. $V_{IN}=12V$ . BST-SW=5V		20		uA
<b>Power MOSFETs and Inductor</b>						
$R_{DS(on)_H}$	High side FET on-resistance			80		m $\Omega$
$R_{DS(on)_L}$	Low side FET on-resistance			42		m $\Omega$
L	Power inductor inductance	At 1MHz		2.3		uH
$R_L$	Power inductor DC-resistance			70		m $\Omega$
<b>Current Limit</b>						
$I_{LIM\_HSD}$	HSD peak current limit		4	4.5	5	A
$I_{LIM\_LSD}$	LSD valley current limit		3.2	4	4.8	A
<b>Switching Frequency</b>						
$F_{SW}$	Switching frequency	$V_{IN}=12V$ , $V_{OUT}=5V$		0.5		MHz
<b>Soft Start Time</b>						
$t_{SS}$	Internal soft-start time			4		ms
<b>Protection</b>						
$V_{OVP}$	Output OVP threshold Hysteresis	$V_{OUT}$ rising		110 5		%
$T_{HIC\_W}$	OCP hiccup wait time			512		Cycles
$T_{HIC\_R}$	OCP hiccup restart time			8192		Cycles
$T_{SD}$	Thermal shutdown threshold Hysteresis	$T_J$ rising		160 25		$^{\circ}C$

**ABSOLUTE MAXIMUM RATINGS**

**Table 2**

Parameter	Rating
Input Supply Voltage	3.8V to +32V
Power Dissipation	2.6W
Thermal Resistance $\theta_{JA}$	39 °C/W
Junction Temperature	125 °C
Lead Temperature(Soldering,10s)	300 °C
Operating Temperature Range	-40 °C to 125 °C
Storage Temperature Range	-65 °C to 150 °C


Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Absolute maximum ratings apply individually only, not in combination. Unless otherwise specified all other voltages referenced to GND.

**Table 3. Thermal Information**

Package Type	$\theta_{JA}^1$	Unit
3-lead TO-220 or TO-263	39	°C/W
Maximum Power Dissipation	2.6	W

$\theta_{JA}$  is specified for the worst-case conditions, i.e.,  $\theta_{JA}$  is specified for device soldered in circuit board for surface mount packages.

**ESD CAUTION**

	<p><b>ESD (electrostatic discharge) sensitive device.</b> Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.</p>
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**PIN CONFIGURATION AND DESCRIPTION**

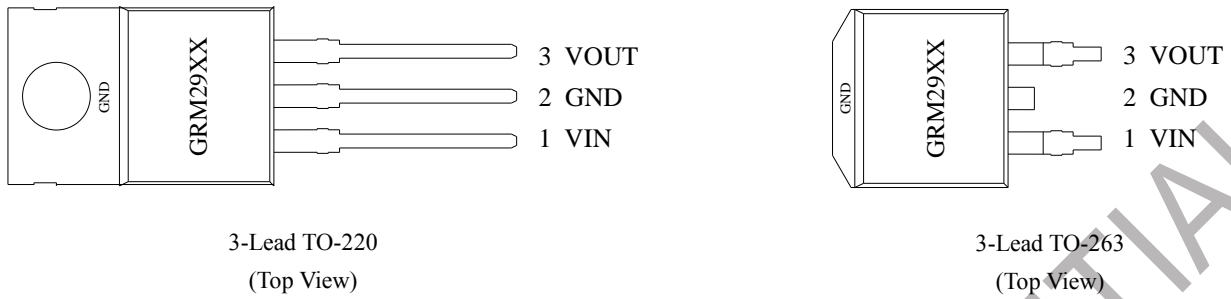


Figure 2. GRM2905 Pin Configuration

**Table 4. Pin Function Descriptions**

Pin No.	Mnemonic	Description
1	VIN	Power supply input. Must be locally bypassed.
2	GND	Power ground. Must be soldered directly to ground plane
3	VOUT	Voltage Output Power Pins, Connect them to out put capacitors

FUNCTIONAL DIAGRAM

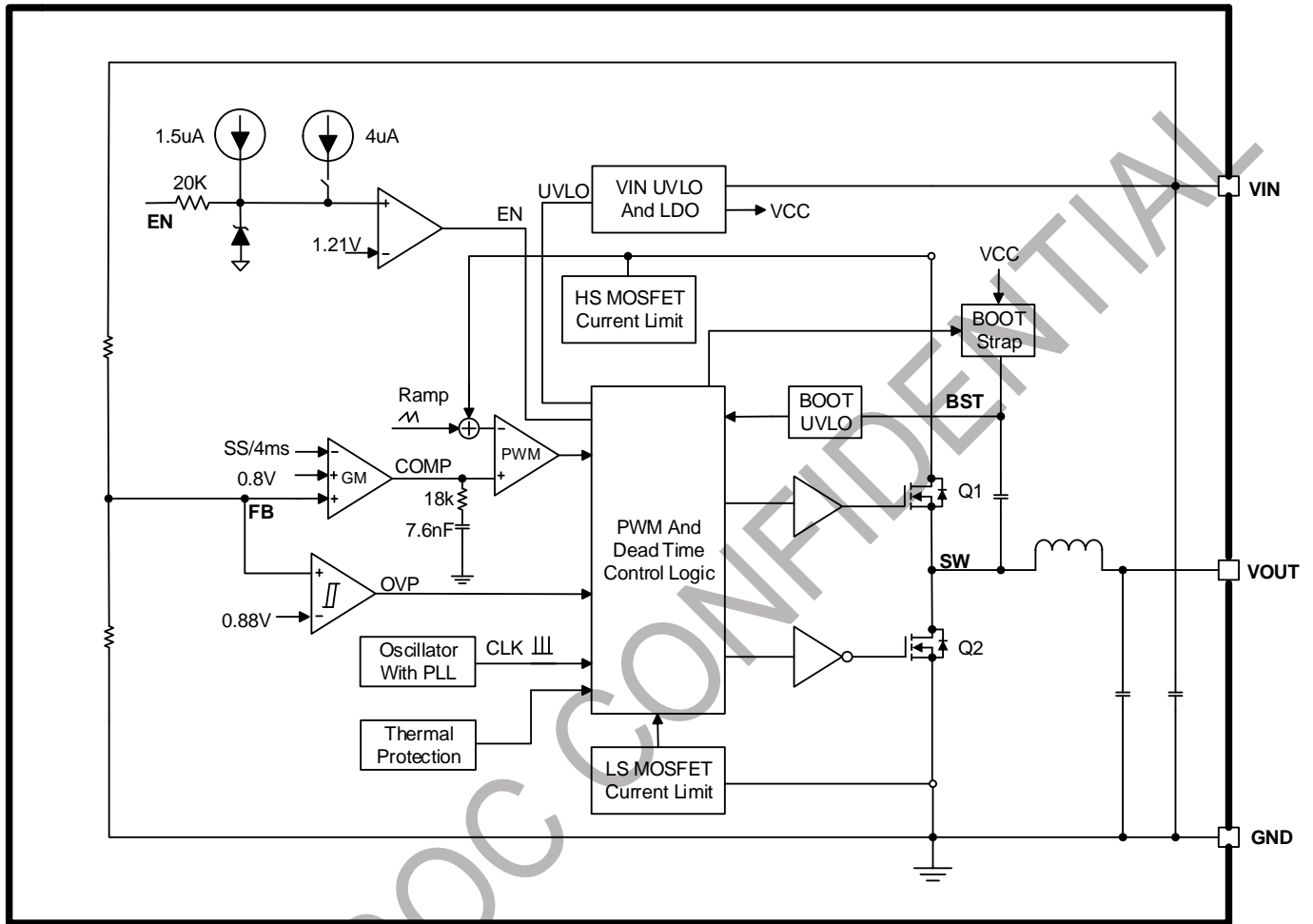


Figure 3. GRM2905 Functional Diagram

## Functional Description

### Overview

The GRM2905 device is 3.8V-32V input, 0.5A output, EMI friendly, fully integrated synchronous buck converters. The device employs fixed frequency peak current mode control. An internal clock with 500KHz frequency initiates turning on the integrated high-side power MOSFET Q1 in each cycle, then inductor current rises linearly and the converter charges output cap. When sensed voltage on high-side MOSFET peak current rising above the voltage of internal COMP (see functional block diagram), the device turns off high-side MOSFET Q1 and turns on low-side MOSFET Q2. The inductor current decreases when MOSFET Q2 is ON. In the next rising edge of clock cycle, the low-side MOSFET Q2 turns off. This repeats on cycle-by-cycle based.

The peak current mode control with the internal loop compensation network and the built-in 4ms soft-start simplify the GRM2905 footprints and minimize the off-chip component counts.

The error amplifier serves the COMP node by comparing the voltage on the FB pin with an internal 0.8V reference voltage. When the load current increases, a reduction in the feedback voltage relative to the reference raises COMP voltage till the average inductor current matches the increased load current. This feedback loop well regulates the output voltage. The device also integrates an internal slope compensation circuitry to prevent sub-harmonic oscillation when duty cycle is greater than 50% for a fixed frequency peak current mode control.

The quiescent current of GRM2905 is 20uA typical under no-load condition and no switching. When disabling the device, the supply shut down current is only 1uA. The GRM2905 works at Pulse Skipping Mode PSM to further increase the power efficiency in light load condition, hence the power efficiency can be achieved up to 88% at 5mA load condition.

The GRM2905 implements the Frequency Spread Spectrum FSS modulation spreading of  $\pm 6\%$  centered 500KHz switching frequency. FSS improves EMI performance by not allowing emitted energy to stay in any one receiver band for a significant length of time. The converter has optimized gate driver scheme to achieve switching node voltage ringing-free without sacrificing the MOSFET switching time to further damping high frequency radiation EMI noise.

The hiccup mode minimizes power dissipation during prolonged output overcurrent or short conditions. The hiccup wait time is 512 cycles and the hiccup restart time is 8192 cycles. The GRM2905 device also features full protections including cycle-by-cycle high-side MOSFET peak current limit, over-voltage protection, and over-temperature protection.

### VIN Power

The GRM2905 is designed to operate from an input voltage supply range between 3.8V to 32V, at least 0.1uF decoupling ceramic cap is recommended to bypass the supply noise. If the input supply locates more than a few inches from the converter, an additional electrolytic or tantalum bulk capacitor or with recommended 22uF may be required in addition to the local ceramic bypass capacitors.

### Under Voltage Lockout UVLO

The GRM2905 Under Voltage Lock Out (UVLO) default startup threshold is typical 3.5V with VIN rising and shutdown threshold is 3.1V with VIN falling. The more accurate UVLO threshold can be programmed through the precision enable threshold of EN pin.

### Peak Current Limit and Hiccup Mode

The GRM2905 has cycle-by-cycle peak current limit with sensing the internal high side MOSFET Q1 current during overcurrent condition. While the Q1 turns on, its conduction current is monitored by the internal sensing circuitry. Once the high-side MOSFET Q1 current exceeds the limit, it turns off immediately. If the Q1 over current time exceeds 512 switching cycles (hiccup waiting time), the buck converter enters hiccup mode and shuts down. After 8192 cycles off, the buck converter restarts to power up. The hiccup modes reduce the power dissipation in over current condition.

### Over Voltage Protection and Minimum On-time

Both GRM2905 features buck converter output over voltage protection (OVP). If the output feedback pin voltage exceeds 110% of feedback reference voltage (0.8V), the converter stops switching immediately. When the output feedback pin voltage drops below 105% of feedback reference voltage, the converter resumes to switching. The OVP function prevents the connected output circuitry damaged from unpredictable overvoltage. Featured feedback overvoltage protection also prevents dynamic voltage spike to damage the circuitry at load during fast loading transient.

The high-side MOSFET Q1 has minimum on-time 80ns typical limitation. While the device operates at minimum on-time, further increasing VIN results in pushing output voltage beyond regulation point. With output feedback over voltage protection, the converter skips pulse by turning off high-side MOSFET Q1 and prevents output running away higher to damage the load.

### PSM Working Modes

In heavy load condition, the GRM2905 forces the device operating at forced Pulse Width Modulation (PWM) mode. When the load current decreasing, the internal COMP net voltage decreases as the inductor current down. With the load current further decreasing, the COMP net voltage decreases and be clamped at a voltage corresponding to the 600mA peak inductor current. When the load current approaches zero, the GRM2905 enter Pulse Skipping Mode (PSM) mode to increase the converter power efficiency at light load condition. When the inductor current decreases to zero, zero-cross detection circuitry on high-side MOSFET Q1 forces the Q1 off till the beginning of the next switching cycle. The buck converter does not sink current from the load when the output load is light and converter works in PSM mode.

### Low Drop-out Regulation

To support the application of small voltage-difference between Vout and Vin, the Low Drop Out (LDO) Operation is implemented by the GRM2905. The Low Drop Out Operation is triggered automatic when the off time of the high-side power MOSFET exceeds the minimum off time limitation.

In low drop out operation, high-side MOSFET remains ON as long as the BST pin to SW pin voltage is higher than BST UVLO threshold. When the voltage from BST to SW drops below 2.35V, the high-side MOSFET turns off and low-side MOSFET turns on to recharge bootstrap capacitor periodically in the following several switching cycles. Only 100ns of low side MOSFET turning on in each refresh cycle minimizes the output voltage ripple. Low-side MOSFET may turn on for several times till bootstrap voltage is charged to higher than 2.7V for high-side

MOSFET working normally. Then high-side MOSFET turns on and remains on until bootstrap voltage drops to trigger bootstrap UVLO again. Thus, the effective duty cycle of the

switching regulator during Low Drop-out LDO operation can be very high even approaching 100%.

During ultra-low voltage difference of input and output voltages, i.e. the input voltage ramping down to power down, the output can track input closely thanks to LDO operation mode.

#### **Thermal Shutdown**

Once the junction temperature in the GRM2905 exceeds 160°C, the thermal sensing circuit stops converter switching and restarts with the junction temperature falling below 125°C. Thermal shutdown prevents the damage on device during excessive heat and power dissipation condition.

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**APPLICATIONS INFORMATION**

**Typical Application**

This section describes the external components selection for the GRM2905. The typical application circuit is shown in Figure 4.

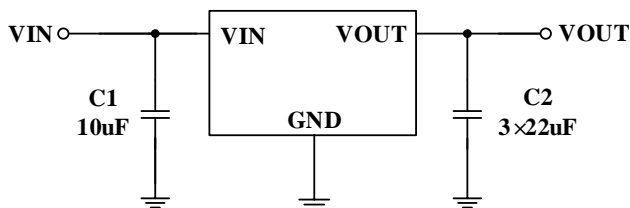


Figure 4. Typical Application Circuit

**Table 5. Design Parameters**

Design Parameters	Example Value
Input Voltage	24V
Output Voltage	5V
Output Current	0.5A
Output Voltage Ripple (peak to peak)	Light Load 40mV
	Heavy Load 30mV
Switching Frequency	500KHz

**Table 6. Input and Output Capacitor Selection**

V <sub>OUT</sub>	C <sub>IN</sub>	C <sub>OUT</sub>
3.3V	10uF	3*22uF
5.0V	10uF	3*22uF

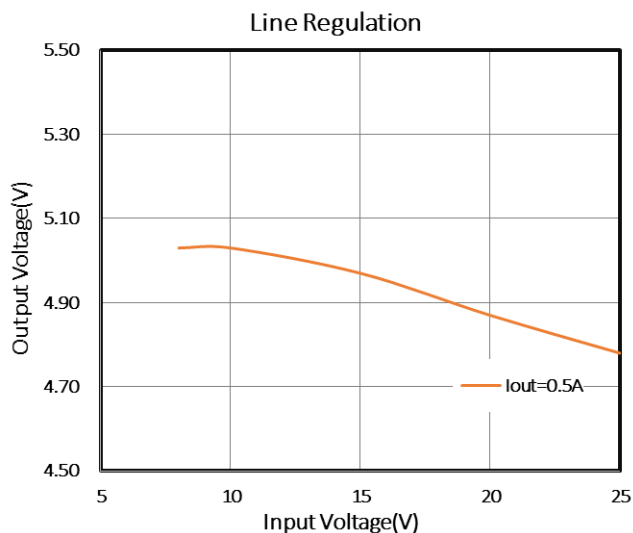


Figure 6. Line Regulation

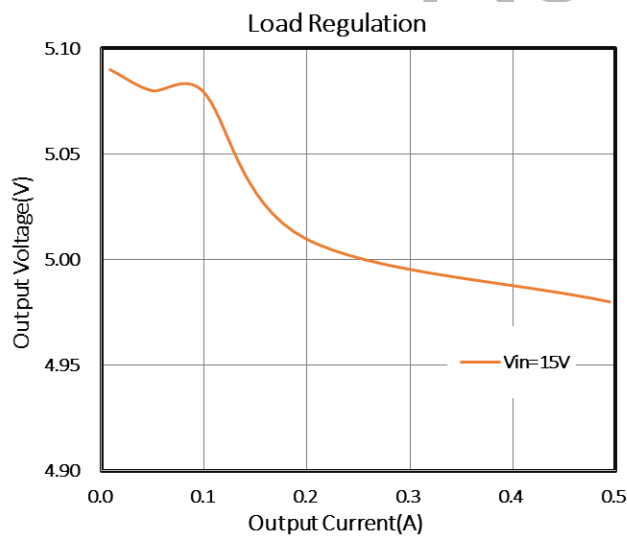


Figure 5. Load Regulation

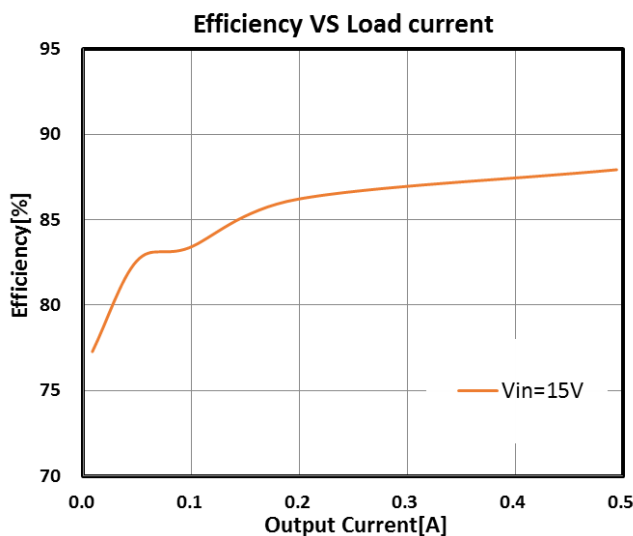


Figure 7. Efficiency



PCB LAYOUT GUIDELINE

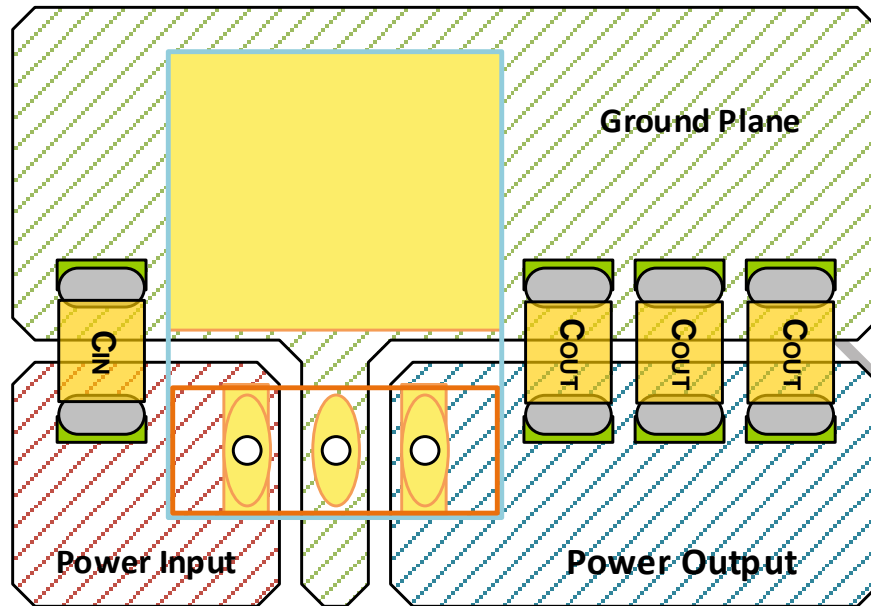


Figure 8. PCB Layout Guideline

Application Waveforms

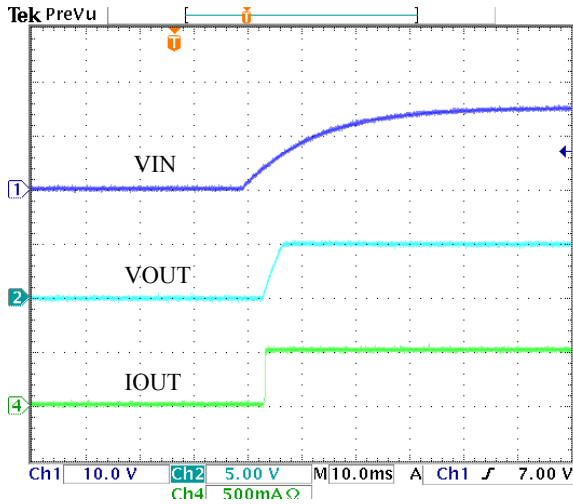


Figure 9. Power Up  
VIN=15V, VOUT=5V, IOU=0.5A

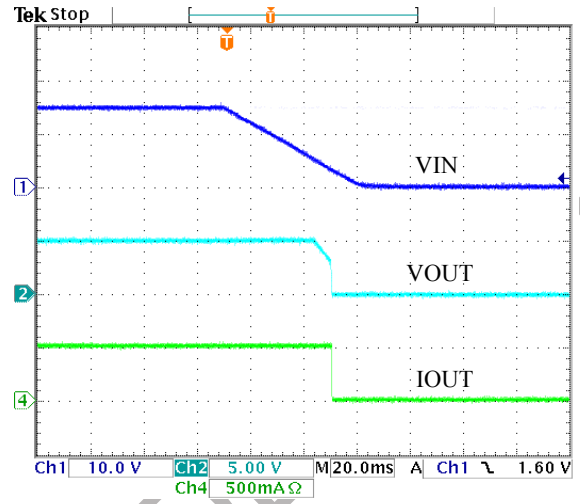


Figure 10. Power Down  
VIN=15V, VOUT=5V, IOU=0.5A

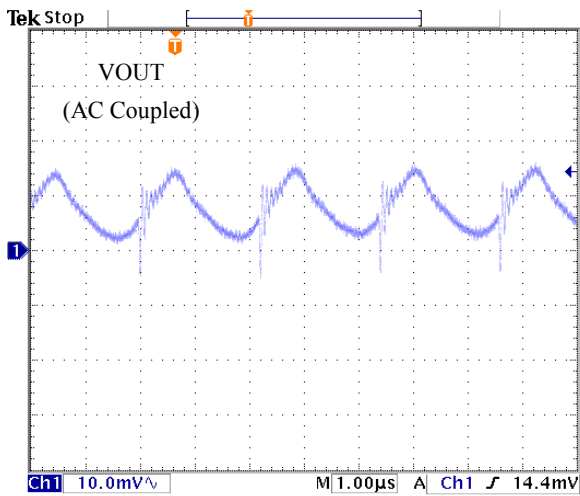


Figure 11. Output Ripple  
VIN=15V, VOUT=5V, IOU=0.5A

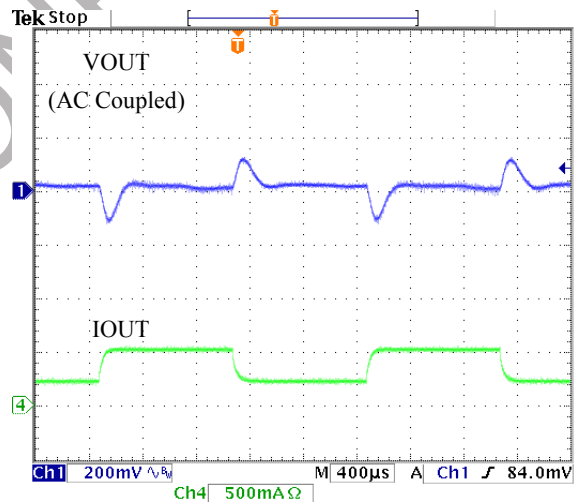


Figure 12. Load Transient  
VIN=15V, VOUT=5V, IOU Step 0.2A to 0.5A

PACKAGE DRAWING

TO-220

Unit: mm

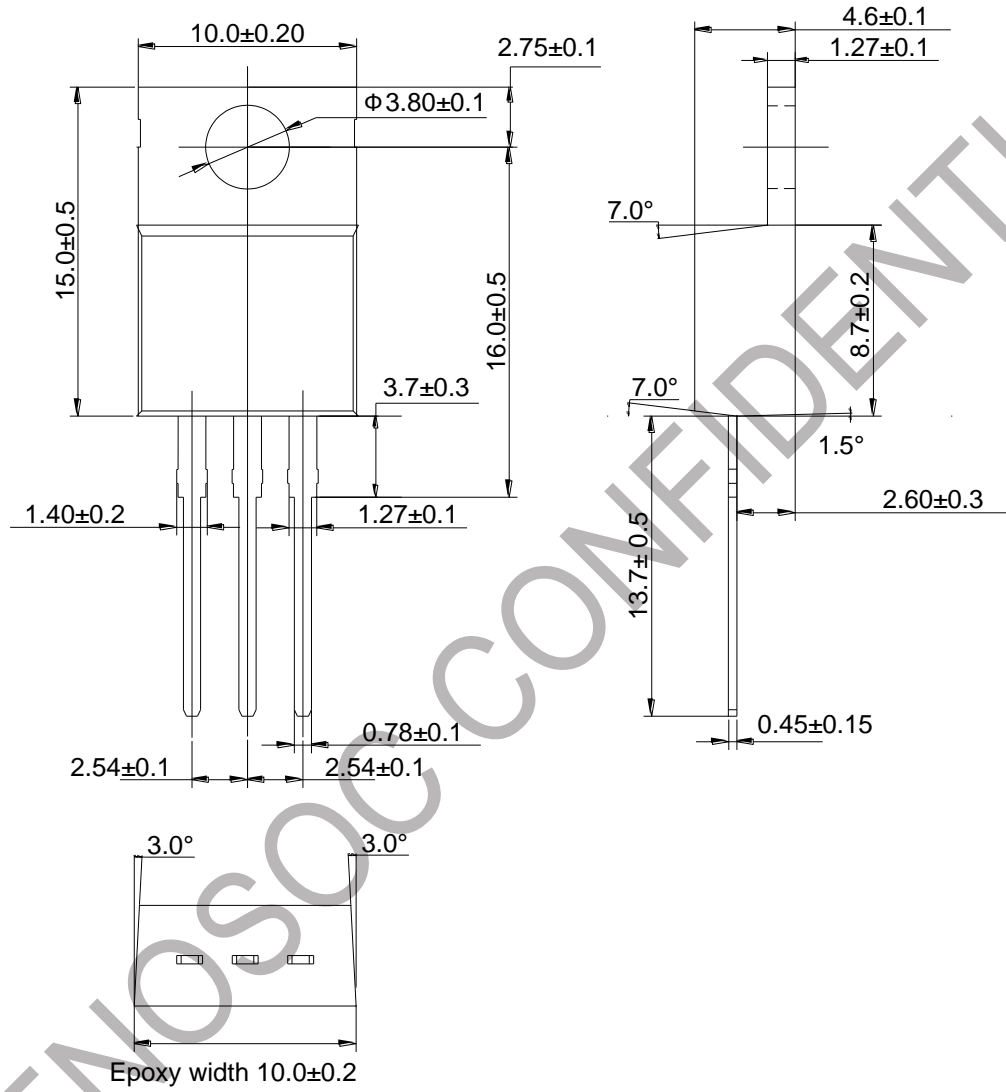


Figure 13. 3-Lead TO-220 Package Outline

TO-263

Unit: mm

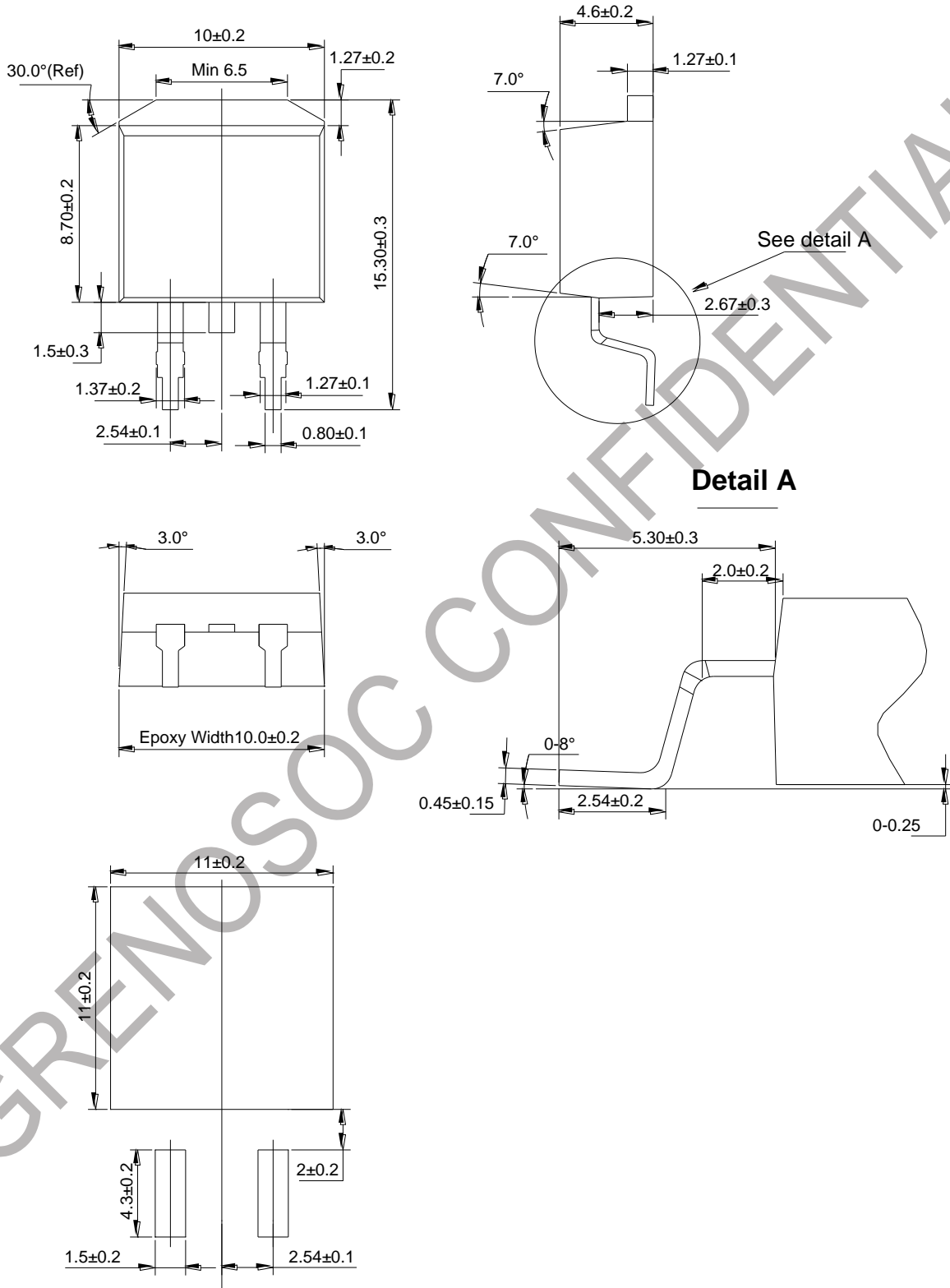
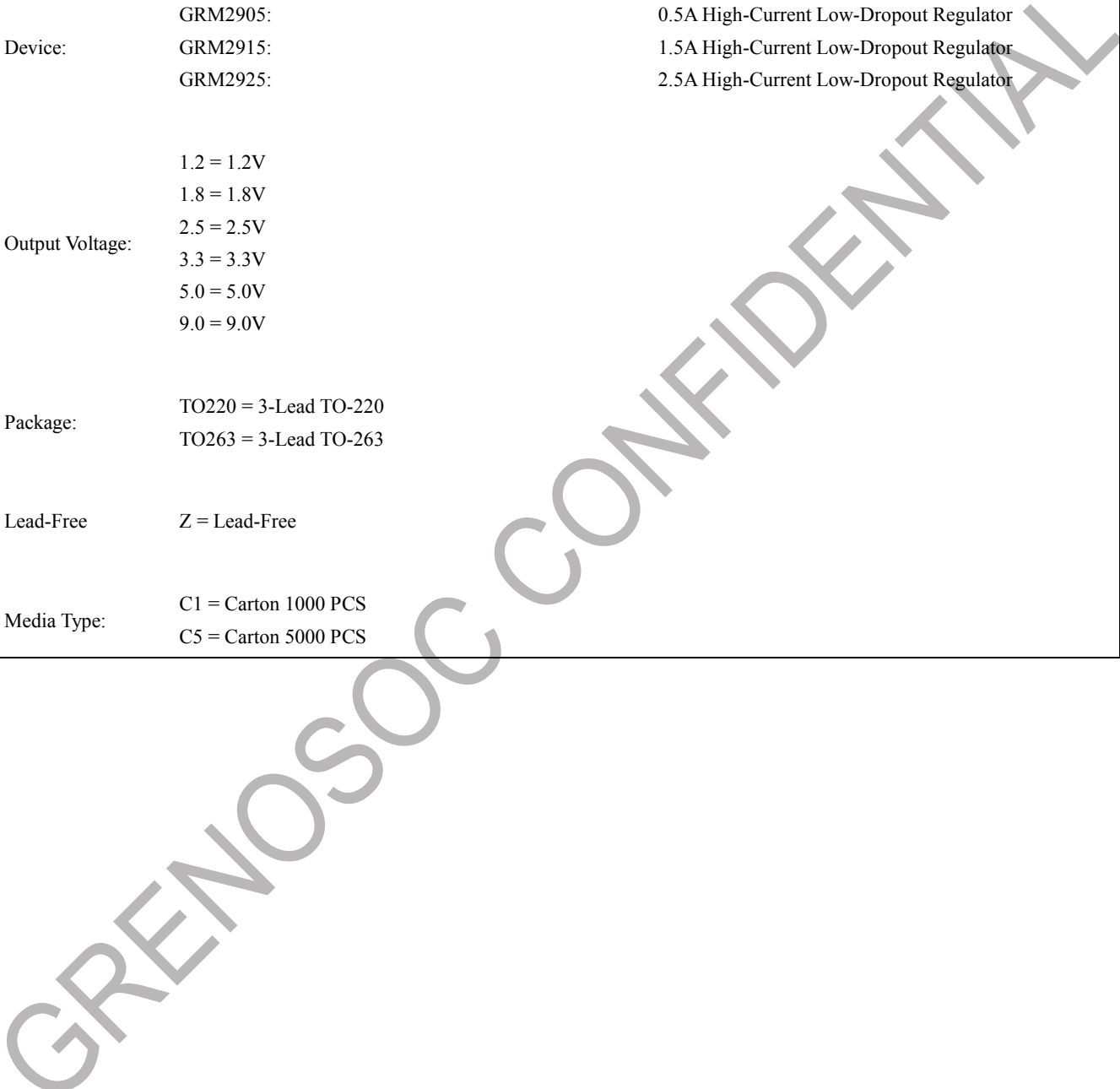


Figure 14. 3-Lead TO-263 Package Outline

**PRODUCT IDENTIFICATION SYSTEM**

PART NO. - XX    XXXXX    X    -    XX  
 Device    Voltage    Package    Lead-Free    Media Type

Device:	GRM2905:	0.5A High-Current Low-Dropout Regulator
	GRM2915:	1.5A High-Current Low-Dropout Regulator
	GRM2925:	2.5A High-Current Low-Dropout Regulator
Output Voltage:	1.2 = 1.2V	
	1.8 = 1.8V	
	2.5 = 2.5V	
	3.3 = 3.3V	
	5.0 = 5.0V	
	9.0 = 9.0V	
Package:	TO220 = 3-Lead TO-220	
	TO263 = 3-Lead TO-263	
Lead-Free	Z = Lead-Free	
Media Type:	C1 = Carton 1000 PCS	
	C5 = Carton 5000 PCS	



## ORDERING INFORMATION

Device	NO.	Ordering Code	Output voltage	Package	Shipping
GRM2905	1	GRM2905-1.2TO220Z-C1	1.2V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	2	GRM2905-1.2TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	3	GRM2905-1.2TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	4	GRM2905-1.2TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton
	5	GRM2905-1.8TO220Z-C1	1.8V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	6	GRM2905-1.8TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	7	GRM2905-1.8TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	8	GRM2905-1.8TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton
	9	GRM2905-2.5TO220Z-C1	2.5V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	10	GRM2905-2.5TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	11	GRM2905-2.5TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	12	GRM2905-2.5TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton
	13	GRM2905-3.3TO220Z-C1	3.3V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	14	GRM2905-3.3TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	15	GRM2905-3.3TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	16	GRM2905-3.3TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton
	17	GRM2905-5.0TO220Z-C1	5.0V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	18	GRM2905-5.0TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	19	GRM2905-5.0TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	20	GRM2905-5.0TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton
	21	GRM2905-9.0TO220Z-C1	9.0V	3-Lead TO-220 (Lead-Free)	1000 / Carton
	22	GRM2905-9.0TO220Z-C5		3-Lead TO-220 (Lead-Free)	5000 / Carton
	23	GRM2905-9.0TO263Z-C1		3-Lead TO-263 (Lead-Free)	1000 / Carton
	24	GRM2905-9.0TO263Z-C5		3-Lead TO-263 (Lead-Free)	5000 / Carton