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Linear LED Driver for High-Voltage LED Lamps

General Description

The RT7322 is a simple and robust constant-current regulator designed to provide a cost-effective solution for driving high-voltage LEDs in LED lamp applications. The RT7322 is equipped with a proprietary control mechanism to improve the utilization of high-voltage LEDs. The RT7322 allows users to set the regulated current levels (WQFN-20L 5x5 Package) for various LED lamps. It also provides low pin-count SOP-8 (Exposed Pad) package with customized current setting to meet various application requirements. In addition, the RT7322 also provides a thermal regulation protection, instead of traditional thermal shutdown, to suppress the rise of the temperatures in LED lamps and prevent the LED lamps from flicker.

Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

Features

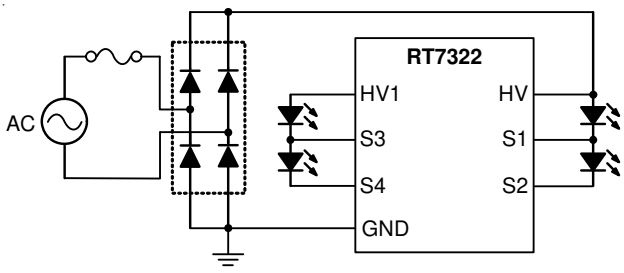
- **AC Input Voltage Range : 90 to 130V_{RMS}**
- **No Electrolytic Capacitor and Transformer Required**
- **Improved LED Utilization**
- **Programmable LED Current**
- **Thermal Regulation Protection**
- **High Power Efficiency**
- **High Power Factor**
- **Easy EMI Solution**
- **Minimized BOM Cost and Space Required**
- **RoHS Compliant and Halogen Free**

Applications

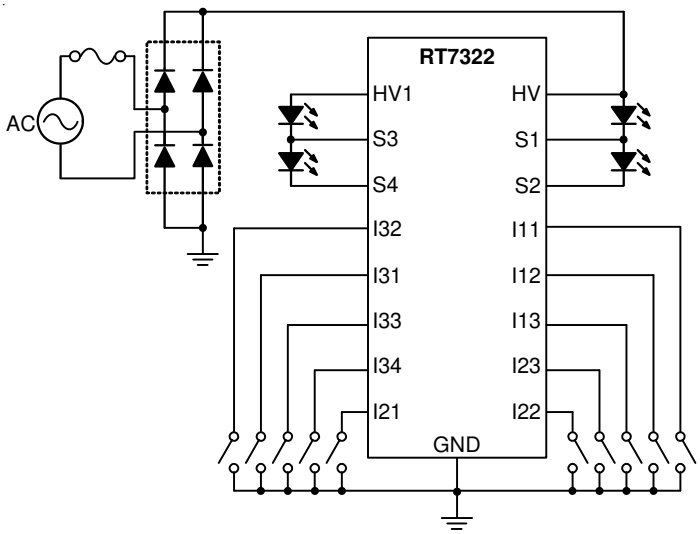
- High-Voltage LED Lamps

Simplified Application Circuit

For SOP-8 (Exposed Pad) Package



For WQFN-20L 5x5 Package



Ordering Information

RT7322□□□□

- Package Type
  - SP : SOP-8 (Exposed Pad-Option 2)
  - QW : WQFN-20L 5x5 (W-Type)
- Lead Plating System
  - G : Green (Halogen Free and Pb Free)
- RT7322 Version Table
  - (Only for SOP-8 (Exposed Pad))

Note :

Richtek products are :

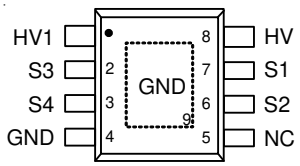
- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

RT7322 Version Table

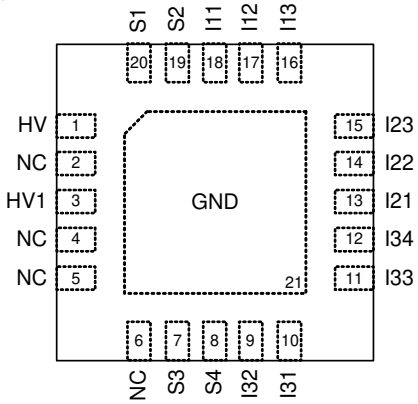
RT7322XYGSP			
Parallel Current ($I_{P\_S1/2}$ and $I_{P\_S3/4}$)	Code (X)	Series Current ($I_{S\_S3/4}$)	Code (Y)
20mA	A	20mA	A
25mA	B	25mA	B
30mA	C	30mA	C
35mA	D	35mA	D
40mA	E	40mA	E
45mA	F	45mA	F
		50mA	G
		55mA	H
		60mA	I
		65mA	J
		70mA	K
		75mA	L
		80mA	M
		85mA	N
		90mA	O

Pin Configurations

(TOP VIEW)



SOP-8 (Exposed Pad)



WQFN-20L 5x5

Functional Pin Description

For SOP-8 (Exposed Pad) Package

Pin No.	Pin Name	Pin Function
1	HV1	Controlled High-Voltage Output. A built-in high-voltage transistor, connected between the HV and HV1 pins, controls the ON or OFF of the supply voltage to the external high-voltage LED connected with HV1 pin.
2	S3	Output of the S3 Current Regulator. The regulated sinking current is set by the internal bounding wires and depends on the requests of users. In the “Parallel operation”, the current (I_{P_S3}) can be set from 20mA to 45mA; in the “Series operation”, the current (I_{S_S3}) can be set from the I_{P_S3} to 90mA.
3	S4	Output of the S4 Current Regulator. Like the S3 pin, the typical regulated currents (I_{P_S3} and I_{P_S4}; I_{S_S3} and I_{S_S4}) of S3 and S4 pins are the same, respectively.
4, 9 (Exposed Pad)	GND	Ground. Connect this pin to system ground with lowest impedance. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
5	NC	No Internal Connection.
6	S2	Output of the S2 Current Regulator. This pin only regulates the sinking current (I_{P_S2}) in the “Parallel operation”. The current (I_{P_S2}), set by the internal bounding wires, is in the range of 20mA to 45mA and depends on the requests of users.
7	S1	Output of the S1 Current Regulator. Like the S2 pin, the typical regulated currents (I_{P_S1} and I_{P_S2}) of S1 and S2 pins are the same.
8	HV	High-Voltage and Bias Voltage Input. Connect this pin to the rectified voltage from AC input.

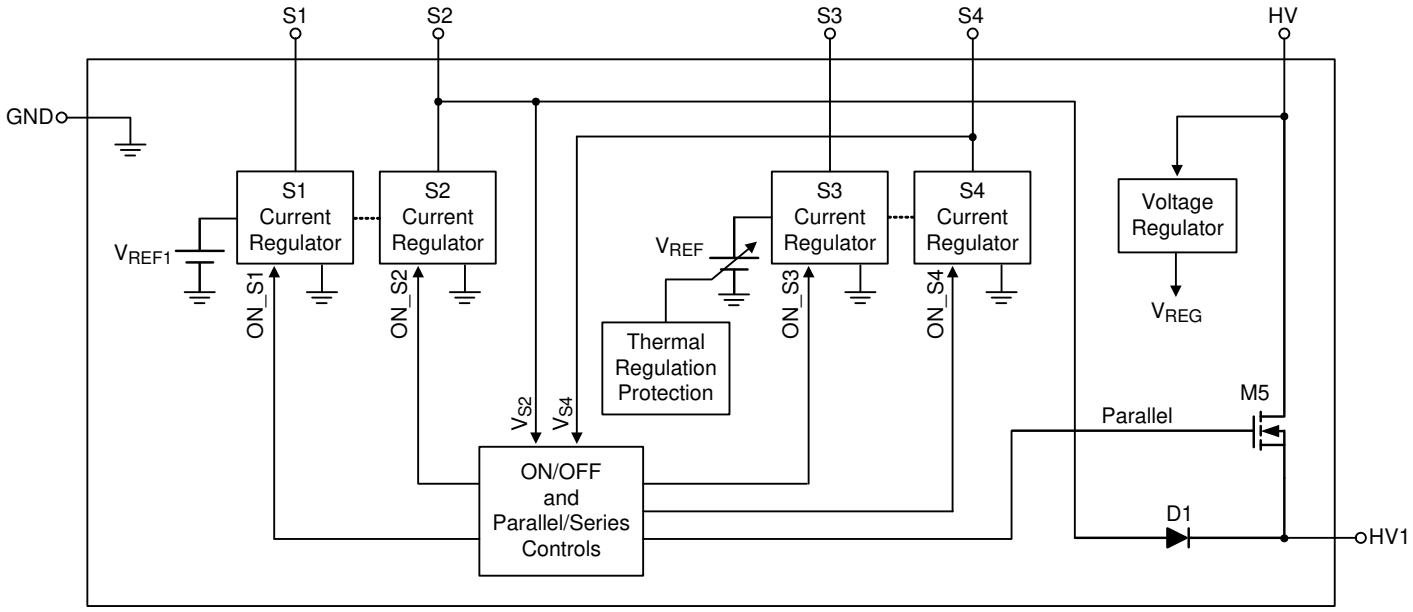
For WQFN-20L 5x5 Package

Pin No.	Pin Name	Pin Function
1	HV	High-Voltage Input. Connect this pin to the rectified voltage from AC input.
2, 4, 5, 6	NC	No Internal Connection.
3	HV1	Controlled High Voltage Output. A built-in high-voltage transistor, connected between the HV and HV1 pins, controls the ON or OFF of the supply voltage to the external high-voltage LED connected with HV1 pin.
7	S3	Output of the S3 Current Regulator. The regulated sinking currents (I_{P_S3} and I_{S_S3}) are easily programmed by users. In the “Parallel operation”, the current (I_{P_S3}) can be set from 20mA to 45mA by using the I21 to I23 pins; in the “Series operation”, the current (I_{S_S3}) can be set from the I_{P_S3} to 90mA by using the I31 to I34 pins. To directly connect the I21/I31, I22/I32, I23/I33 or I34 pin to GND pin, respectively increases the sinking current by 5mA, 10mA 20mA or 40mA. The initial I_{P_S3} is 20mA if the I21 to I23 pins are open.
8	S4	Output Pin of the S4 Current Regulator. Like the S3 pin, the typical regulated currents (I_{P_S3} and I_{P_S4}; I_{S_S3} and I_{S_S4}) of S3 and S4 pins are the same and easily programmed by using the I21 to I23 pins and I31 to I34 pins, respectively.
9	I32	Current Setting Input for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{S_S3} and I_{S_S4}) increase 10mA (typ.).
10	I31	Current Setting Input for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{S_S3} and I_{S_S4}) increase 5mA (typ.).

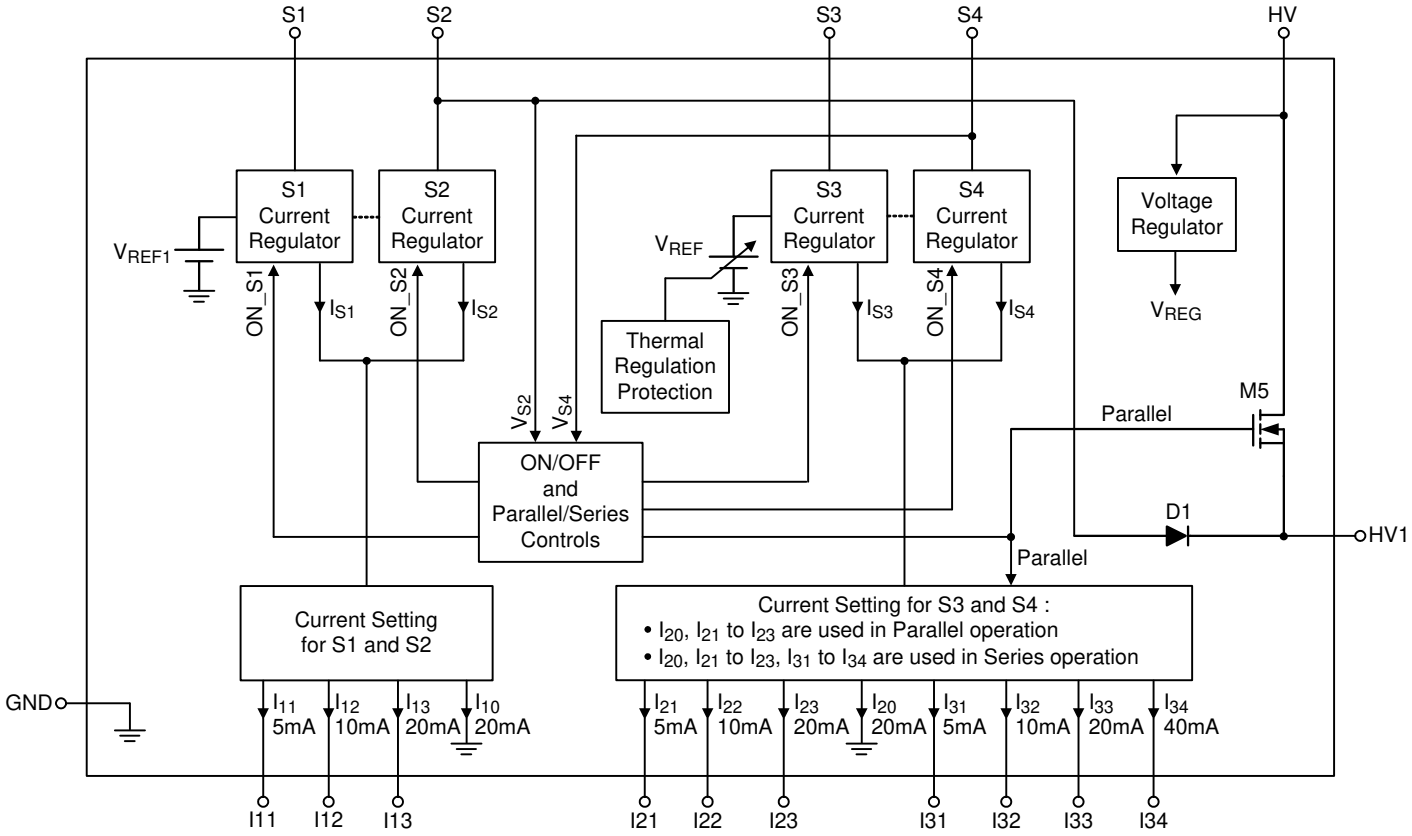
Pin No.	Pin Name	Pin Function
11	I33	Current Setting Input Pin for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{S_S3} and I_{S_S4}) increase 20mA (typ.).
12	I34	Current Setting Input Pin for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{S_S3} and I_{S_S4}) increase 40mA (typ.).
13	I21	Current Setting Input for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S3} and I_{P_S4}) increase 5mA (typ.).
14	I22	Current Setting Input for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S3} and I_{P_S4}) increase 10mA (typ.).
15	I23	Current Setting Input Pin for S3 and S4 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S3} and I_{P_S4}) increase 20mA (typ.).
16	I13	Current Setting Input for S1 and S2 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S1} and I_{P_S2}) increase 20mA (typ.).
17	I12	Current Setting Input for S1 and S2 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S1} and I_{P_S2}) increase 10mA (typ.).
18	I11	Current Setting Input for S1 and S2 pins. If this pin is directly connected to GND, the regulated currents (I_{P_S1} and I_{P_S2}) increase 5mA (typ.).
19	S2	Output of the S2 Current Regulator. This pin only regulates the sinking current (I_{P_S2}) in the “Parallel operation”. To open or directly connect the I11, I12 or I13 pin to GND pin can easily program the sinking current from 20mA to 45mA by users.
20	S1	Output of the S1 Current Regulator. Like the S2 pin, the typical regulated currents (I_{P_S1} and I_{P_S2}) of S1 and S2 pins are the same.
21 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Function Block Diagram

For SOP-8 (Exposed Pad) Package



For WQFN-20L 5x5 Package



Operation

Constant-Current Regulator

In Figure 1, each constant-current regulator in the RT7322 consists of an output high-voltage MOSFET, programmable current-sense resistors, an error amplifier and a reference voltage (V_{REF}).

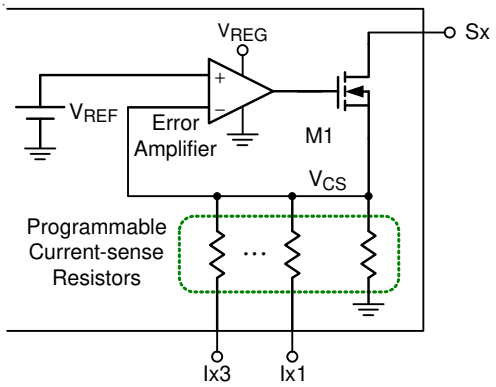


Figure 1

The error amplifier, designed with high DC gain, compares the current signal (V_{CS}) on the current-sense resistors and the V_{REF} to generate an amplified error signal. The error signal regulates the output MOSFET (M1) to control the sinking current on Sx pin at the programmed current level. In addition, the operating Sx voltage (V_{Sx}) must be higher than the minimum Sx voltage (V_{Sx_MIN}). Otherwise, the output current might not be regulated at the programmed level (I_{Sx_SET}). The V_{Sx_MIN} is approximately calculated by the following equation:

$$V_{Sx\_MIN} = 3000 \times I_{Sx\_SET}^2 + 4 \quad (V)$$

For the SOP-8 (Exposed Pad) package, the Sx regulated currents are set by the internal bounding wires and depends on the requests of users. For the WQFN-20L 5x5 package, the regulated currents are easily programmed by users.

Parallel and Series Operations

For improving the utilization of high-voltage LEDs, the RT7322 is equipped with a proprietary control mechanism which switches the operating mode in either "parallel operation" or "series operation".

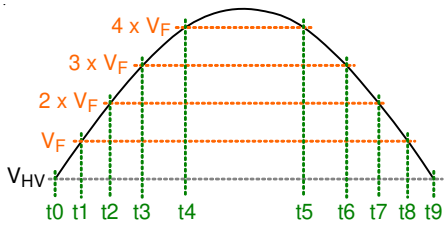


Figure 2. Timing Chart

Figure 3 shows the current paths in parallel operation. In this operation (during t1 to t3 and t6 to t8), an internal MOSFET are turned on to provide a current path from HV to HV1 pins. In this operation, the S1 and S3 regulators is turned on when the input voltage (V_{HV}) is greater than the LED forward voltage (V_F) and smaller than 2 x V_F (during t1 to t2 and t7 to t8); the S2 and S4 regulators take over the current regulations when the V_{HV} is approximately larger then 2 x V_F and smaller than 3 x V_F (during t2 to t3 and t6 to t7). The typical regulated currents are calculated by the following equations:

$$I_{P\_S1/2} = I_{10} + I_{11\ (if\ I11\ =\ GND)} + I_{12\ (if\ I12\ =\ GND)} + I_{13\ (if\ I13\ =\ GND)}$$

$$I_{P\_S3/4} = I_{20} + I_{21\ (if\ I21\ =\ GND)} + I_{22\ (if\ I22\ =\ GND)} + I_{23\ (if\ I23\ =\ GND)}$$

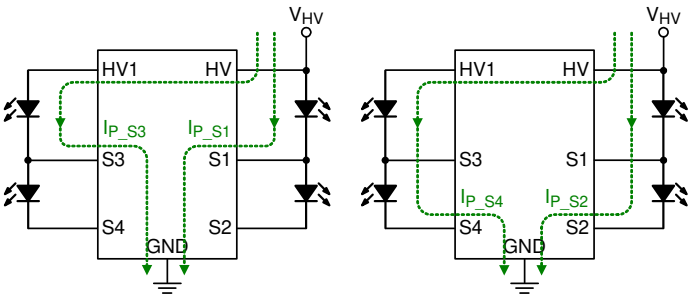


Figure 3. Current Paths in Parallel Operation

As the V_{HV} is approximately larger then 3 x V_F (during t3 to t6), the series operation is active. Figure 4 shows the current paths in series operation. In this operation, the internal MOSFET is turned off and a built-in high-voltage diode provides a current path from S2 to HV1 pins. In this operation, the S3 regulator is turned on when the V_{HV} is approximately greater than 3 x V_F and smaller than 4 x V_F (during t3 to t4 and t5 to t6); the S4 regulator takes over

the current regulation when the V_{HV} is approximately larger then 4 x V_F (during t4 to t5). The typical regulated currents are calculated by the following equations :

$$I_{S\_S3/4} = I_{P\_S3/4} + I_{31\ (if\ I31 = GND)} + I_{32\ (if\ I32 = GND)} + I_{33\ (if\ I33 = GND)} + I_{34\ (if\ I34 = GND)}$$

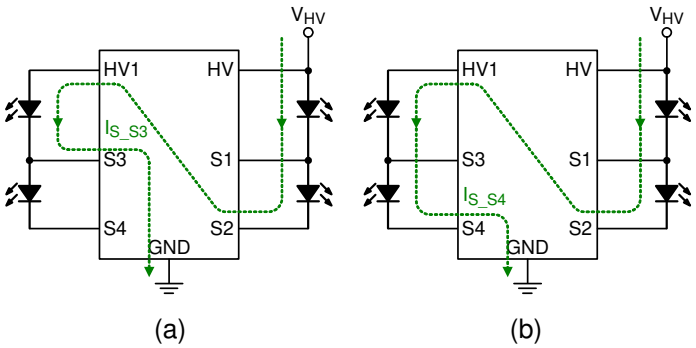


Figure 4. Current Paths in Series Operation

Thermal Regulation Protection

When a LED lamp operates in high ambient temperature conditions, it needs a thermal protection to limit the temperatures for protecting LED lamps and ensuring system reliability. The RT7322 provides a thermal regulation protection, instead of traditional thermal shutdown, to suppress the rise of temperatures. When the IC junction temperature rise above 140°C (typ.), this function starts to gradually reduce the regulated LED current (I_{S_S3} and I_{S_S4}), depending on the rise of the junction temperature. Meanwhile, the system power dissipation is also reduced. Finally, the temperatures in the system will be well controlled and enter their steady-states. The function can achieve both of the two targets : to protect LED lamps and to prevent them from flicker.

Absolute Maximum Ratings (Note 1)

- HV to GND Voltage, V_{HV} ---------- –0.3V to 500V
- HV1 to GND Voltage ---------- –0.3V to 500V
- HV to HV1 Voltage ---------- –0.3V to 300V
- S1, S2 to GND Voltage (at off-state) ---------- –0.3V to 300V
- S3, S4 to GND Voltage (at off-state) ---------- –0.3V to 200V
- S1, S2, S3, S4 to GND Voltage (at on-state) ---------- –0.3V to 100V
- I11, I12, I13, I21, I22, I23, I31, I32, I33, I34 to GND Voltage ---------- –0.3V to 5V
- Typical Value of Programmed S1, S2 Current ---------- 45mA
- Typical Value of Programmed S3, S4 Current ---------- 90mA
- Power Dissipation, P_D @ T_A = 25°C
  - SOP-8 (Exposed Pad) ---------- 3.44W
  - WQFN-20L 5x5 ---------- 3.54W
- Package Thermal Resistance (Note 2)
  - SOP-8 (Exposed Pad), θ_{JA} ---------- 29°C/W
  - SOP-8 (Exposed Pad), θ_{JC} ---------- 2°C/W
  - WQFN-20L 5x5, θ_{JA} ---------- 28.2°C/W
  - WQFN-20L 5x5, θ_{JC} ---------- 7.1°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  - HBM (Human Body Model), All pins except HV ---------- 2kV
  - MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- HV Supply Voltage, V_{HV} ---------- 1 to 200V
- S1, S2, S3, S4 Input DC Voltage (at on-state) ---------- 1V to 90V
  (at off-state) ---------- 1V to 180V
- Typical Value of Programmed S1, S2 Current ---------- 20mA to 45mA
- Typical Value of Programmed S3, S4 Current ---------- 20mA to 90mA
- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Electrical Characteristics

(T_A = 25°C, unless otherwise specification)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Output Current Section						
Initial S1 to S4 Regulated Current	I_{10}, I_{20}	V_{S1}, V_{S2}, V_{S3}, or V_{S4} = 30V, I11 to I34 = Open	19	20	21	mA
Increment of S1, S2 Regulated Current	I_{11}	V_{S1} or V_{S2} = 30V, I_{11} = GND, I12 = I13 = Open	4.75	5	5.25	mA
	I_{12}	V_{S1} or V_{S2} = 30V, I12 = GND, I11 = I13 = Open	9.5	10	10.5	
	I_{13}	V_{S1} or V_{S2} = 30V, I13 = GND, I11 = I12 = Open	19	20	21	
Increment of S3, S4 Regulated Current	I_{21}	V_{S3} or V_{S4} = 30V, I21 = GND, I22 = I23 = Open	4.75	5	5.25	mA
	I_{22}	V_{S3} or V_{S4} = 30V, I22 = GND, I21 = I23 = Open	9.5	10	10.5	
	I_{23}	V_{S3} or V_{S4} = 30V, I23 = GND, I21 = I22 = Open	19	20	21	
	I_{31}	V_{S3} or V_{S4} = 30V, I31 = GND, I32 = I33 = I34 = Open	4.75	5	5.25	
	I_{32}	V_{S3} or V_{S4} = 30V, I32 = GND, I31 = I33 = I34 = Open	9.5	10	10.5	
	I_{33}	V_{S3} or V_{S4} = 30V, I33 = GND, I31 = I32 = I34 = Open	19	20	21	
	I_{34}	V_{S3} or V_{S4} = 30V, I34 = GND, I31 = I32 = I33 = Open	38	40	42	
Off-State Leakage Currents						
S1 Leakage Current		V_{S2} = 20V, V_{S1} = 300V	--	--	300	μA
S2 Leakage Current		V_{S2} = 300V	--	--	300	μA
S3 Leakage Current		V_{S4} = 20V, V_{S3} = 200V	--	--	300	μA
Current Capability						
HV-to-HV1 Current		V_{HV} = 5V, V_{HV1} = 0V	80	--	--	mA
S2-to-HV1 Current		V_{S2} = 1.2V, V_{HV1} = 0V	60	--	--	mA

Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Application Circuit

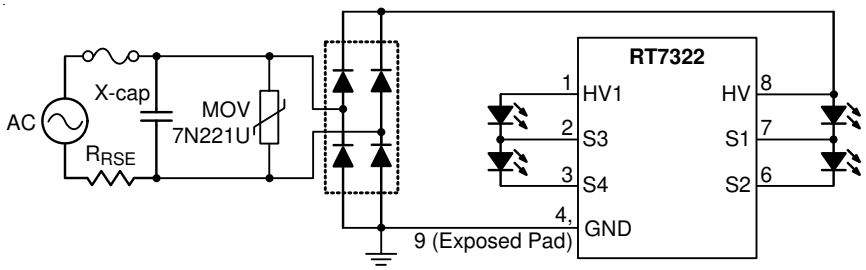


Figure 5. For SOP-8 (Exposed Pad) Package

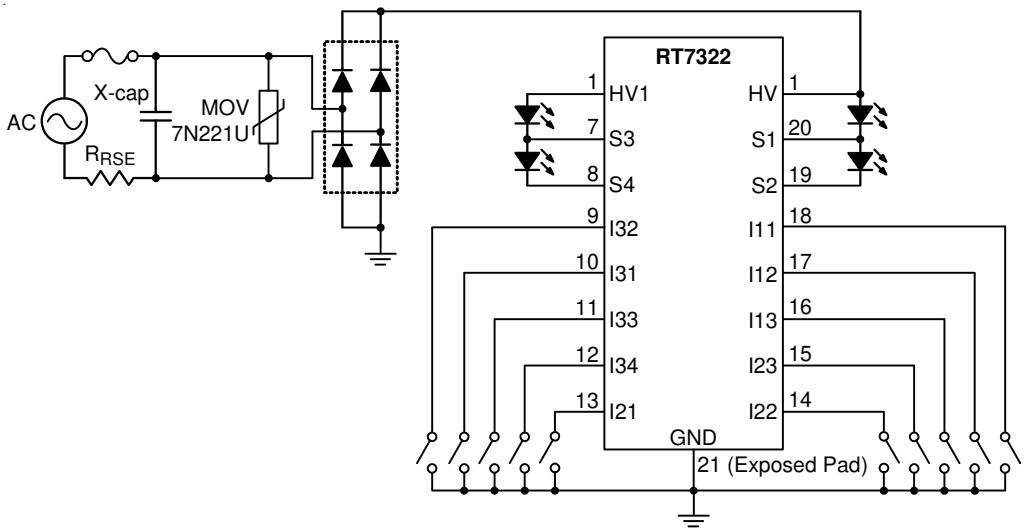


Figure 6. For WDFN-20L 5x5 Package

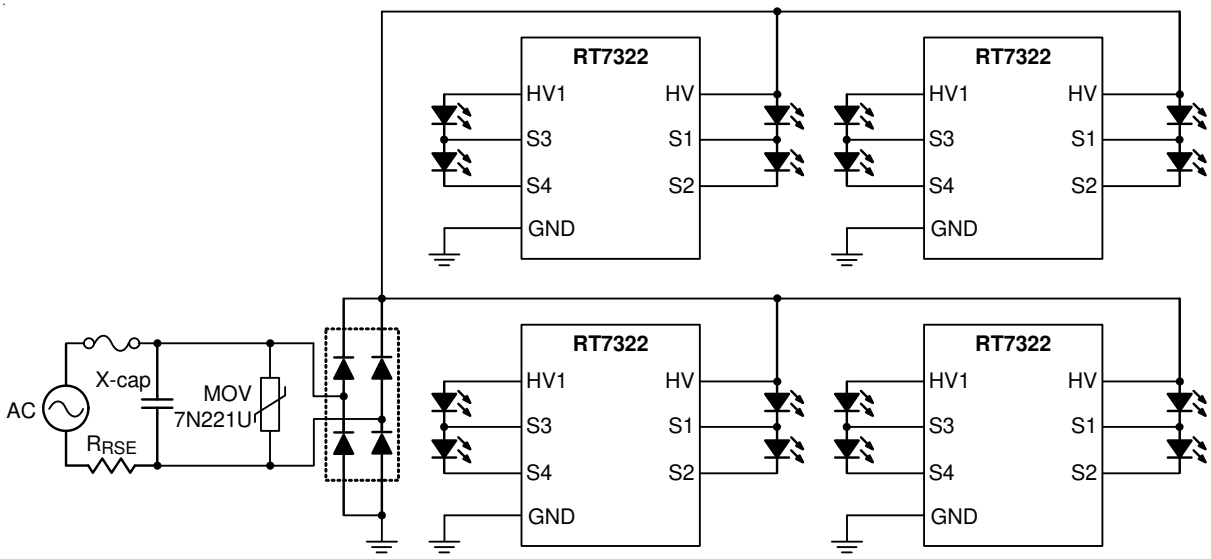


Figure 7. 24W to 25W Output Power Application

Application Information

Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For SOP-8 (Exposed Pad) package, the thermal resistance, θ_{JA}, is 29°C/W on a standard JEDEC 51-7 four-layer thermal test board. For WQFN-20L 5x5 package, the thermal resistance, θ_{JA}, is 28.2°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (29°C/W) = 3.44W for SOP-8 (Exposed Pad) package

$P_{D(MAX)}$ = (125°C – 25°C) / (28.2°C/W) = 3.54W for WQFN-20L 5x5 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 8 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

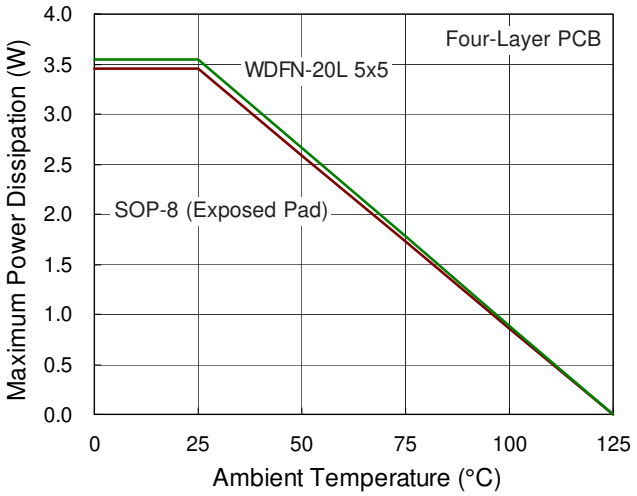


Figure 8. Derating Curve of Maximum Power Dissipation

Layout Considerations

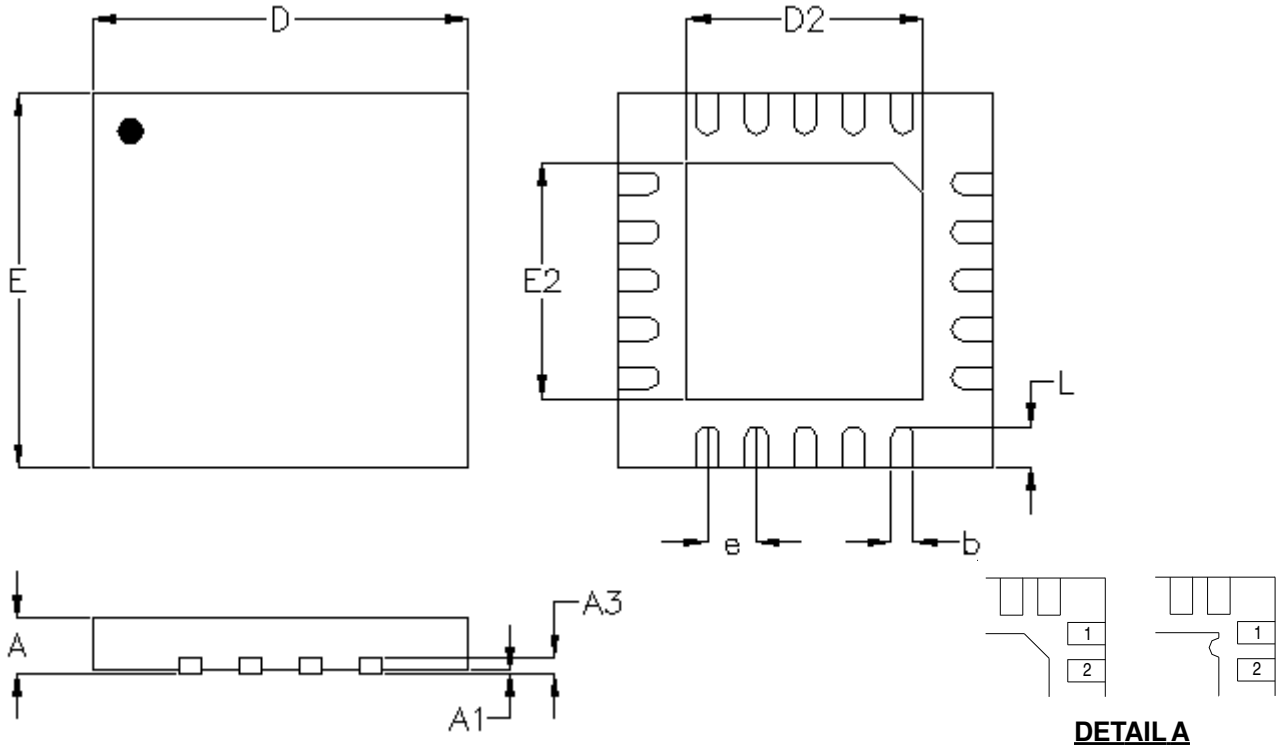
- The thermal resistance θ_{JA} of SOP-8 (Exposed Pad) or WQFN-20L 5x5 is determined by the package design and the PCB design. However, the package design had been designed. If possible, it's useful to increase thermal performance by the PCB design. The thermal resistance θ_{JA} can be decreased by adding a copper under the exposed pad of SOP-8 (Exposed Pad) or WQFN-20L 5x5 package. The Exposed Pad can be connected the ground or an isolated plane on the PCB.
- The used current setting pins (I11 to I33) must be directly connect to GND pin with shortest copper paths. Not-used current setting pins (I11 to I33) must be kept open.

Selection Guide of the RT7322 in the SOP-8 (Exposed Pad) Package

The S1 to S4 sinking current of the RT7322 in the SOP-8 (Exposed Pad) package depends on the requests of users and set by the internal bounding wires. In the "Parallel operation", the LED current range can be set from 20mA to 45mA; in thea "Series operation", the LED current range can be set from 20mA to 90mA. The following table shows the selection guide of the RT7322 in the SOP-8 (Exposed Pad) package for the applications with input power from 5W to 7W.

Input Power	Parallel Current	Series Current	Ordering Information
5W	30mA	50mA	RT7322CGGSP
6W	30mA	65mA	RT7322CJGSP
6.6W	30mA	70mA	RT7322CKGSP
7W	40mA	75mA	RT7322ELGSP

Outline Dimension



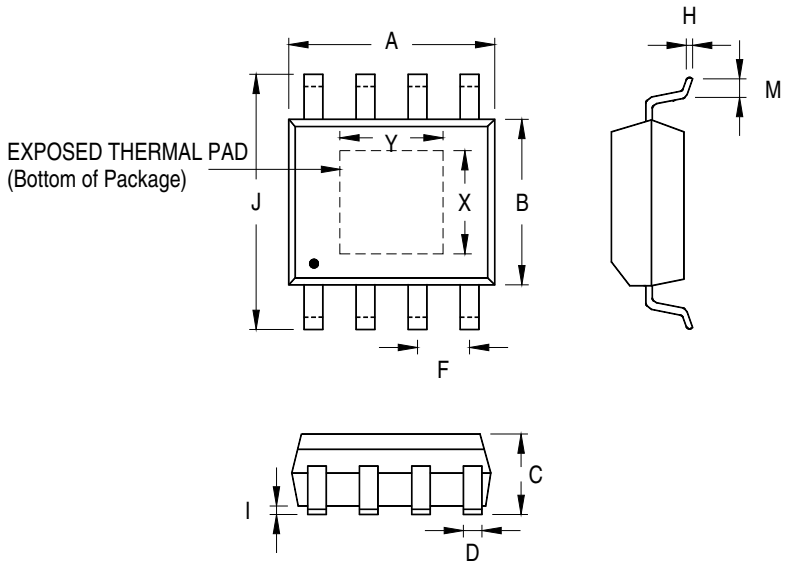
DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.250	0.350	0.010	0.014
D	4.900	5.100	0.193	0.201
D2	3.100	3.200	0.122	0.126
E	4.900	5.100	0.193	0.201
E2	3.100	3.200	0.122	0.126
e	0.650		0.026	
L	0.500	0.600	0.020	0.024

W-Type 20L QFN 5x5 Package



Symbol		Dimensions In Millimeters		Dimensions In Inches	
		Min	Max	Min	Max
A		4.801	5.004	0.189	0.197
B		3.810	4.000	0.150	0.157
C		1.346	1.753	0.053	0.069
D		0.330	0.510	0.013	0.020
F		1.194	1.346	0.047	0.053
H		0.170	0.254	0.007	0.010
I		0.000	0.152	0.000	0.006
J		5.791	6.200	0.228	0.244
M		0.406	1.270	0.016	0.050
Option 1	X	2.000	2.300	0.079	0.091
	Y	2.000	2.300	0.079	0.091
Option 2	X	2.100	2.500	0.083	0.098
	Y	3.000	3.500	0.118	0.138

8-Lead SOP (Exposed Pad) Plastic Package

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