

■ GENERAL DESCRIPTION

DK0xxG series is a high performance AC-DC power converter with 650V GaN HEMT device integrated. With quasi-resonant control mode, DK0xxG series can detect the voltage over drain-source voltage across the GaN device and turn on the device when V_{DS} oscillate to the lowest point. Thus, system overall efficiency and EMI performance can be greatly improved.

DK0xxG series greatly simplifies the design and manufacture of AC-DC SMPS, especially those requiring high conversion efficiency and high power density. DK0xxG has complete protection functions including output over-voltage protection (OVP), V_{CC} over-voltage protection, over-temperature protection (OTP), open-loop protection, output over-current protection (OCP), etc.\

DK0xxG series adopt PDFN5*6 and DFN8*8 package.

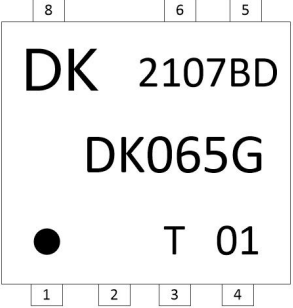
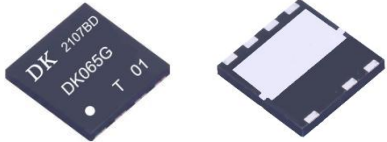
■ FEATURES

- ◆ Up to 250KHz switching frequency
- ◆ 650V e-mode GaN HEMT integrated
- ◆ Standby power consumption less than 50mW
- ◆ Quasi-resonant control mode
- ◆ Built-in valley detection circuit and valley locking circuit with optimized algorithm
- ◆ Built-in demagnetization detection circuit
- ◆ Built-in frequency jittering circuit effectively improves EMI performance
- ◆ Built-in power compensation circuit to ensure consistent maximum output power over global input voltage
- ◆ Halogen-free and ROHs compliant

■ APPLICATIONS

- ◆ High power density SMPS power adapter/charger
- ◆ Laptop adapters, tablet adapters, set-top box adapters, etc.
- ◆ Auxiliary and standby power

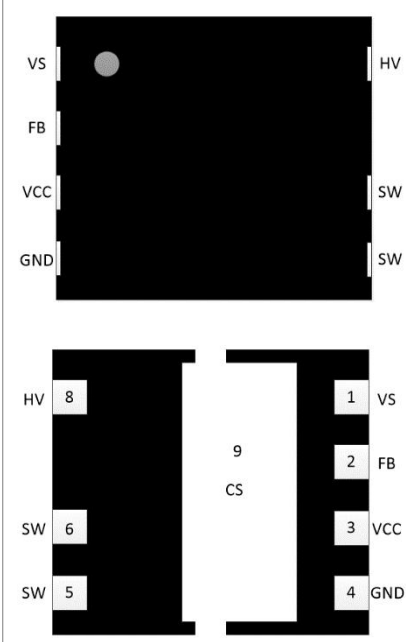
■ MARKING DIAGRAMS

Marking	Note		
DK	DK Semiconductor		
2107	2021 7 th Batch of Production		
BD	Internal Code		
065G	Product No.		
T 01	Testing Code		

■ PACKAGE/ORDER INFORMATION

Order Codes	Package	Typical Power
		85~265VAC
DK012G	PDFN5*6	12W
DK020G	PDFN5*6	20W
DK025G	PDFN5*6	25W
DK036G	PDFN5*6	36W
DK045G	PDFN5*6	45W
DK065G	DFN8*8	65W
DK075G	DFN8*8	75W

■ PIN CONFIGURATION

		Pin No.	Pin Name	Description
		1	VS	Auxiliary winding voltage Vaux detection (used to detect input voltage for power compensation and output voltage detection). This pin is also for transformer demagnetization detection.
		2	FB	Opto-coupler feedback input pin that controls the chip to modulate I_{pk} based on FB voltage.
		3	V _{CC}	Power supply. When V _{CC} exceeds 18V, the chip starts to work. When V _{CC} drops below 5.5V, the chip stops working. During normal operation, V _{CC} voltage range is 7.5V~28V.
		4	GND	Ground reference.
		5	SW	The drain terminal of GaN device, connect to the primary inductor.
		6		
		7	NC	NC.
		8	HV	Connect to rectifier for high voltage start-up. Also used for X-cap discharge.
		9	CS	Current sense.



■ **ABSOLUTE MAXIMUM RATINGS** ($T_A=25^{\circ}\text{C}$ Unless otherwise noted)

Rating	Symbol	Value	Unit
GaN HEMT V_{DS} voltage	$V_{DS(MAX)}$	650	V
HV voltage	$V_{HV(MAX)}$	700	V
HV start-up input current	$I_{HV(MAX)}$	3	mA
V_{CC} voltage	V_{CC}	-0.3~28	V
V_{CC} current	I_{CC}	0.6	mA
FB voltage	$V_{FB(MAX)}$	5.5	V
VS voltage	$V_{VS(MAX)}$	5.5	V
CS voltage	$V_{CS(MAX)}$	5	V
Total dissipation power	$P_{D(MAX)}$	2(PDFN5*6)	W
		3(DFN8*8)	W
Thermal resistance	θ_{JA}	5.5(PDFN5*6)	$^{\circ}\text{C}/\text{W}$
		4(DFN8*8)	$^{\circ}\text{C}/\text{W}$
Maximum junction temperature	$T_{J(MAX)}$	150	$^{\circ}\text{C}$
Storage temperature range	T_{STG}	-40~150	$^{\circ}\text{C}$
Maximum soldering temperature	T_W	260	$^{\circ}\text{C}, 10\text{s}$

Note: Absolute maximum ratings are those values beyond which the device could be permanently damaged.

■ **ELECTRIC CHARACTERISTICS** ($T_A=25^{\circ}\text{C}$ Unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
V_{CC} Power Supply						
V_{CC} Start-up Voltage	$V_{CC(start)}$	Input 90Vac-----265Vac	16.6	18	19.4	V
V_{CC} Start-up Current	I_{start}	$V_{CC}=0\text{V}$	2.0	2.2	2.4	mA
V_{CC} Restart Voltage	$V_{CC(reset)}$		5.1	5.5	5.9	V
V_{CC} Operating Voltage	$V_{CC(on)}$		7.5	12	28	V
V_{CC} Operating Current	$I_{CC(on)}$	$V_{CC}=10\text{V}$	0.1	0.4	0.6	mA
V_{CC} Overvoltage Protection Point	$V_{CC(OVP)}$		25.8	28	30.2	V
Leakage Current when Start-up Circuit Turned Off	$I_{HV(off)}$	$V_{HV}=325\text{V}$	18.4	20	21.6	μA
Bus Voltage						
System Start-Up Threshold Voltage	V_{Brown_in}		103	112	121	V
Brown-out Threshold	V_{Brown_out}		82	90	97	V
Brown-in Start Current	I_{Brown_in}		128	140	151	μA

Brown-out Dropout Current	$I_{\text{Brown_out}}$		103	112	121	μA
Power Compensation Current	I_{comp}		460	500	540	μA
Feedback						
FB Voltage Threshold	V_{FB}		0.92		5	V
FB Open Circuit Voltage	$V_{\text{FB(open)}}$		4.9	5.3	5.7	V
FB Short Circuit Current	$I_{\text{FB(short)}}$	FB pin shorted to GND, measuring FB current	184	200	216	μA
FB Frequency Conversion Starting Point	$V_{\text{FB(vf)}}$		2.2	2.4	2.6	V
FB Standby	$V_{\text{FB(std)}}$		0.8	0.9	1.0	V
Maximum Turn-on Time	$t_{\text{on(MAX)}}$		13.8	15	16.2	μs
CS Sampling						
Internal Current Limit Peak Voltage	V_{ILIM1}	$V_{\text{in}}=373V_{\text{DC}}$	552	600	648	mV
		$V_{\text{in}}=100V_{\text{DC}}$	662	720	778	mV
Minimum Peak Current Voltage	$V_{\text{CS(MIN)}}$		138	150	162	mV
Leading Edge Blanking Time	t_{LEB1}		276	300	324	ns
VS Demagnetization Detection						
Demagnetization Threshold Voltage	$V_{\text{TH_VS}}$		27.6	30	32.4	mV
VS Overvoltage Protection	$V_{\text{VS_OVP}}$		3.3	3.6	3.9	V
Timer Section						
Jittering Range	f_{M}		9.2	10	10.8	%
Maximum On-time	$T_{\text{on_MAX}}$		13.8	15	16.2	μs
Maximum Switching Cycle	T_{MAX}		36.8	40	43.2	μs
Power Section						
GaN HEMT $R_{\text{DS(on)}}$	$R_{\text{DS(on)}}$	DK012G		2200		m Ω
		DK020G		1200		m Ω
		DK025G		800		m Ω
		DK036G/DK045G		400		m Ω
		DK065G		260		m Ω
		DK075G		160		m Ω
Protection						
Overload Protection Restart Time	t_{OPP}		1840	2000	2160	ms
Short Circuit Protection Restart Time	t_{short}		1840	2000	2160	ms
Output Short Circuit Detection Time	t_{osd}	$t_{\text{osd}}=t_{\text{LEB1}}+120\text{ns}$	386	420	454	ns
OTP	T_{SD}	Junction Temperature	130		150	$^{\circ}\text{C}$

■ **OPERATION DESCRIPTION**

DK0xxG is a current mode controlled quasi-resonant flyback AC-DC power converter with GaN HEMT device integrated. DK0xxG operates in discontinuous current conduction mode (DCM). In this mode, the main power device turns on when the transformer core energy is fully released and the primary inductor resonates with GaN HEMT output to a minimum value. In this case, system overall efficiency and EMI performance both can be improved.

◆ **Start-up**

During start-up, DK0xxG charges the external V_{CC} capacitor through the internal HV current source connected to HV and V_{CC} pins. When the V_{CC} voltage rises to $V_{CC(start)}$, HV current source is turned off and start-up process is finished.

◆ **Input Voltage Brown-in Detection**

After start-up, DK0xxG generates 3 consecutive PWM cycles to detect input voltage. If the bus voltage is larger than $112V_{DC}$, DK0xxG judges that the bus voltage is powered-on successfully and enters soft start. If the bus voltage is not powered-on successfully within 6 consecutive PWM cycles, DK0xxG stops PWM output. After 16ms, DK0xxG will restart. After V_{CC} is powered up to $V_{CC(start)}$, system enters the input voltage power-on detection.

◆ **Soft Start**

After input voltage is successfully powered-on, DK0xxG enters soft-start. To prevent output voltage from overshooting, to stop the transformer core from being saturated and to stop primary and secondary power devices from being overstressed, DK0xxG has a built-in soft-start circuit.

◆ **Input Voltage Brown-out Detection**

During normal operation, input voltage

brown-out detection: If the bus voltage is continuously detected to be lower than $90V_{DC}$ within 32ms, DK0xxG judges as input voltage brown-out and PWM is stopped. 16ms later, DK0xxG will restarted and V_{CC} will rise up to $V_{CC(start)}$. DK0xxG will enter input voltage detection status.

◆ **Demagnetization Detection**

DK0xxG detects demagnetization of the transformer by sensing the VS pin voltage and sampling the auxiliary winding voltage to achieve valley turn-on. When the energy stored in the inductor is completely released, the VS voltage starts to drop. When the VS voltage drops below a predetermined value, the controller turns on the GaN device through an internal comparator and enters the next cycle.

◆ **Quasi-resonant (QR) mode**

Quasi-resonant (QR) flyback mode is a type of discontinuous conduction mode (DCM), which means that after the core energy of the transformer is completely released, the primary inductor of the transformer and the output capacitor of the GaN device starts to resonate. The power device turns on when the output capacitor of the GaN device resonates with the primary inductance to a minimum (valley) value.

◆ **Valley Lock**

In order to limit the maximum frequency during QR mode, the traditional solution is frequency clamping. However, this will make the turn-on signal jumps back and forth between two valleys, which will cause minor operating frequency difference which will lead to acoustic noise and output ripple. DK0xxG incorporates valley lock technology to overcome this problem.

◆ **Frequency Jittering**

DK0xxG contains a frequency jittering

circuit to reduce EMI interference. By adding a low-frequency triangular wave voltage to the input of the PWM comparator, the jittering circuit can disperse the peak energy of EMI noise.

◆ **Line Voltage Compensation**

Due to turn off delay of power device, in order to limit max output power at the same level within the whole input voltage range, line voltage compensation circuit is essential. DK0xxG incorporates line voltage compensation circuit to insure consistency of over current point.

◆ **Overload/Short Circuit Protection**

DK0xxG senses the CS voltage and judges if the output is overloaded or shorted. If CS voltage exceeds a certain level and holds for a period of time, DK0xxG judges the output is overloaded or shorted and enters overload/short circuit protection.

◆ **Leading Edge Blanking**

Due to the presence of transformer distributed capacitor, there is a current spike at the moment of power device turn-on. To avoid wrong actions, DK0xxG contains a leading edge blanking (LEB) circuit which can effectively filter out the spike current when the power device is turned on.

◆ **Output Overvoltage Protection (OVP)**

DK0xxG can accurately detect the output voltage by sensing the voltage on the auxiliary winding. Therefore, the controller can stop PWM output and protect the overall system when output over voltage happens.

◆ **Over Temperature Protection**

DK0xxG contains an over-temperature protection circuit which detects the junction temperature of the main power device. A threshold value temperature T_{SD} is set to with hysteresis response. If the junction temperature exceeds the over-temperature protection threshold, DK0xxG will restart and hiccup until the junction temperature drops to a certain temperature.

■ **FUNCTION DESCRIPTION**

◆ **High Voltage Starting Circuit**

DK0xxG contains multi-function high voltage (HV) pin. As shown in Figure 1, to achieve fast startup and to reduce standby power consumption, DK0xxG contains a HV startup circuit. Meanwhile, HV pin can accurately monitor the input voltage and enable the internal X-capacitor discharge circuit to

quickly discharge the X-capacitor residual voltage after the input voltage is powered off to meet safety regulation requirements. If the X-capacitor discharge circuit is not required, it can be connected directly to the HV pin through the positive side of the input capacitor.

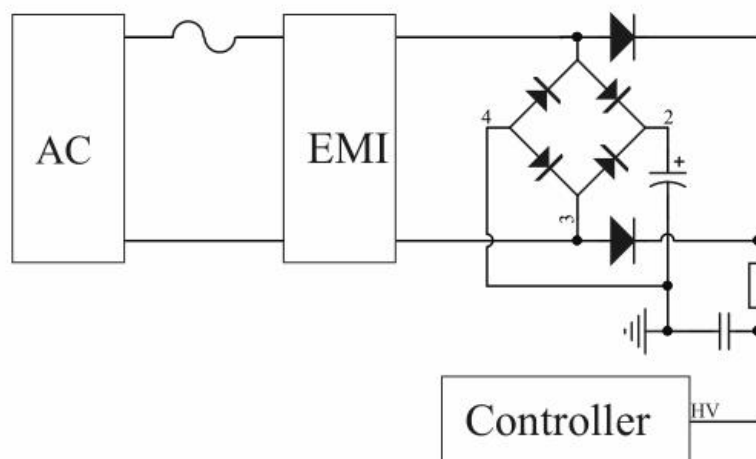


Figure1: High Voltage Start-up Circuit

◆ Feedback Control

DK0xxG adopts cycle-by-cycle current limiting PWM control mode and adjusts the peak current of the cycle by detecting the feedback voltage of V_{FB} . When the power device is turned on, DK0xxG samples the voltage over R_{CS} . When voltage over R_{CS} reaches V_{ILIM1} , DK0xxG turns off the power device and waits for the next cycle.

When load changes, FB voltage will change in a certain range and will hysteresis in order to achieve quasi resonant valley lock. Power device turns on at resonate valley will reduce the turn-on loss. But if the turn-on point switches back and forth between two adjacent valleys, it will cause a large change in the operating frequency, resulting in audio noise and output ripple problems. So when the load is constant, it is essential to ensure that the system turns on at a definite valley instead of switching back and forth between two adjacent valleys.

When load decreases, FB voltage will fall. After $V_{FB} < FB_{(vf)}$, the peak current should not be reduced too fast in order to improve light load efficiency, so operating frequency needs to be reduced. FB voltage is reduced from $FB_{(vf)}$

to $FB_{(std)}$ in this procedure and peak current gradually becomes smaller, minimum to $150\text{mv}/R_{CS}$.

When the load continues to decrease until $FB \text{ voltage} < FB_{(std)}$, the PWM current reference will be maintained at $150\text{mv}/R_{CS}$. After that, the operating frequency will decrease till a minimum of 25KHz.

When $FB \text{ voltage} < FB_{(std)}$, DK0xxG will enter standby mode and stop PWM output. When $FB > FB_{(std)} + 50\text{mV}$, it will exit standby mode and will output some PWM pulses again to maintain the set output voltage. When the $FB \text{ voltage} < FB_{(std)}$ is detected again, it will enter standby mode again and stop PWM output. This intermittent mode can effectively reduce the switching frequency to improve the light load efficiency.

◆ 25KHz Minimum Frequency Clamp

Operating frequency of quasi-resonant control mode flyback SMPS will increase with load. In order to avoid audio noise, DK0xxG clamps the lowest frequency to 25KHz, which can effectively avoid entering audio noise frequency range. As shown in Figure 2.

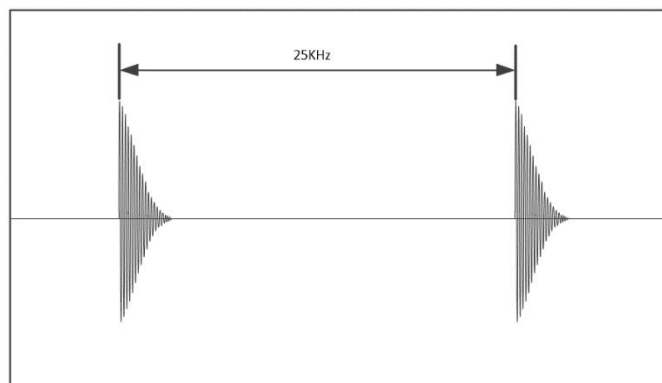


Figure2: 25KHz Minimum Frequency Clamp

◆ V_{CC} Operating Mode

The start-up duration is directly related to the V_{CC} capacitor value. As shown in Figure 3, under light or no-load conditions, the controller operates at the lowest frequency, so the V_{CC} capacitor must be large enough to keep the V_{CC} voltage above $V_{CC(\text{reset})}$.

During start-up, DK0xxG charges the V_{CC} capacitor through a HV start-up circuit. When V_{CC} reaches $V_{CC(\text{start})}$, the HV start-up circuit is turned off and DK0xxG starts to output PWM signal and is powered by the auxiliary winding.

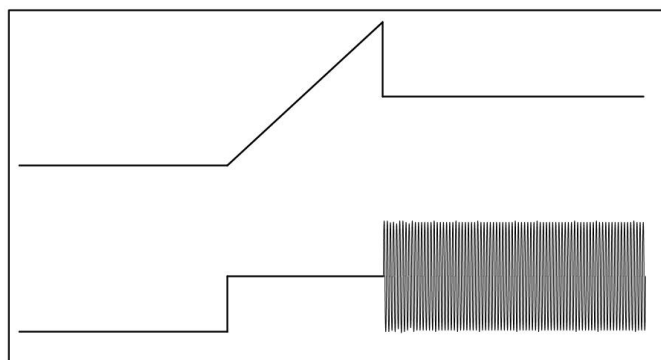


Figure3: V_{CC} Start-up

◆ Demagnetization Detection

The DK0xxG is a flyback SMPS power converter operating in quasi-resonant (QR) mode. The primary power device turns off when the voltage across the sampling resistor R_{CS} reaches V_{ILIM1} . When the voltage across the auxiliary winding of the transformer is below

V_{TH_VS} , the primary power device turns on. In this way, switching loss is reduced and electromagnetic interference (EMI) is improved. As shown in Figure 4, the power device turns on once the VS voltage falls below the demagnetization threshold V_{TH_VS} .

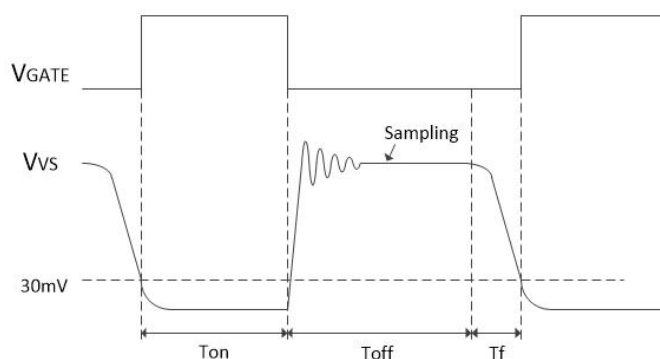


Figure4: Auxiliary Winding Waveform and Demagnetization Detection

◆ Output Over Voltage Protection (OVP)

Output over voltage protection is achieved by detecting the voltage on the VS pin when the primary power device is turned off. The voltage on VS is proportional to the output voltage, and the proportionality factor is related to the turn ratio of the auxiliary winding and the secondary winding, as well as to the pull-up and pull-down resistor voltage division ratio of the auxiliary winding. To ensure a smoother voltage on the VS pin sampled by OVP,

delayed sampling is used to avoid false triggering due to leakage inductance spikes when the primary power device is turned off.

As shown in Figure 5, if the sampled voltage exceeds V_{VS_OVP} , the internal counter starts. When it is detected that the VS voltage exceeds the reference voltage for a continuous 3 cycles, the converter determines that the output OVP is happening and controller stops working.

$$V_{VS} = V_{OUT} * \frac{R_{vsl} * N_A}{(R_{vsh} + R_{vsl}) * N_S}$$

V_{OUT} is the output voltage, N_A is the number of turns of the auxiliary winding, and N_S is the number of turns of the secondary winding, R_{VSH} is the pull-up resistor of the auxiliary winding and $RVSL$ is the pull-down resistor.

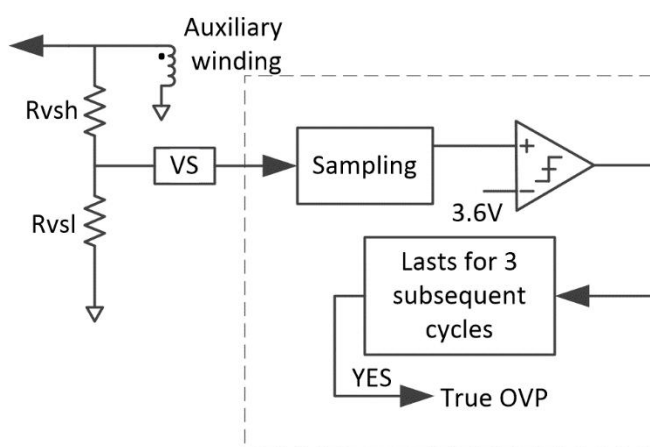


Figure5: Output Over Voltage Protection

◆ Input Over Voltage Protection

The DK0xxG detects the input bus voltage when the primary power device is turned on.

$$V_{Brownin} = I_{Brownin} * R_{vsh} * \frac{N_P}{N_A}$$

$$V_{Brownout} = I_{Brownout} * R_{vsh} * \frac{N_P}{N_A}$$

◆ Line Voltage Power Compensation

DK0XXG adjusts line voltage power compensation by changing R_{vsh} .

$$R_{vsh} = \frac{V_{dc\ max} * N_A}{I_{comp} * N_P}$$

The VS pull-up resistor is determined first to meet the line voltage power compensation.

◆ Valley Lock

Conventional quasi-resonant (QR) flyback converters, the frequency increases as the load decreases, and a maximum frequency limit is usually applied. Maximum frequency limit causes the controller to jump back and forth between adjacent valleys resulting in system

instability and consequently introduce audio noise. Therefore, to avoid such problem, DK0xxG adopts valley lock technique (VLO). When a large change in the load is detected, DK0xxG will lock a new valley. This is shown in Figure 6.

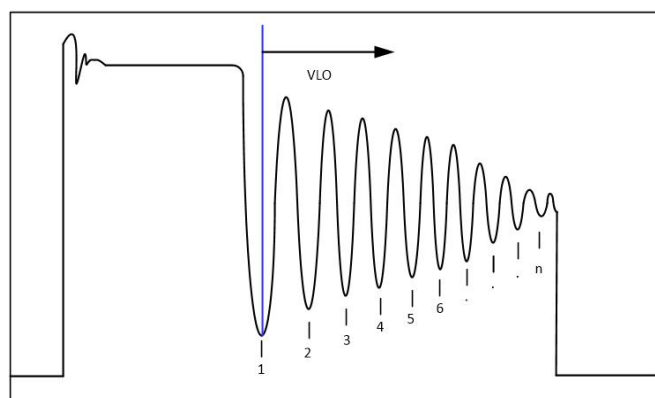
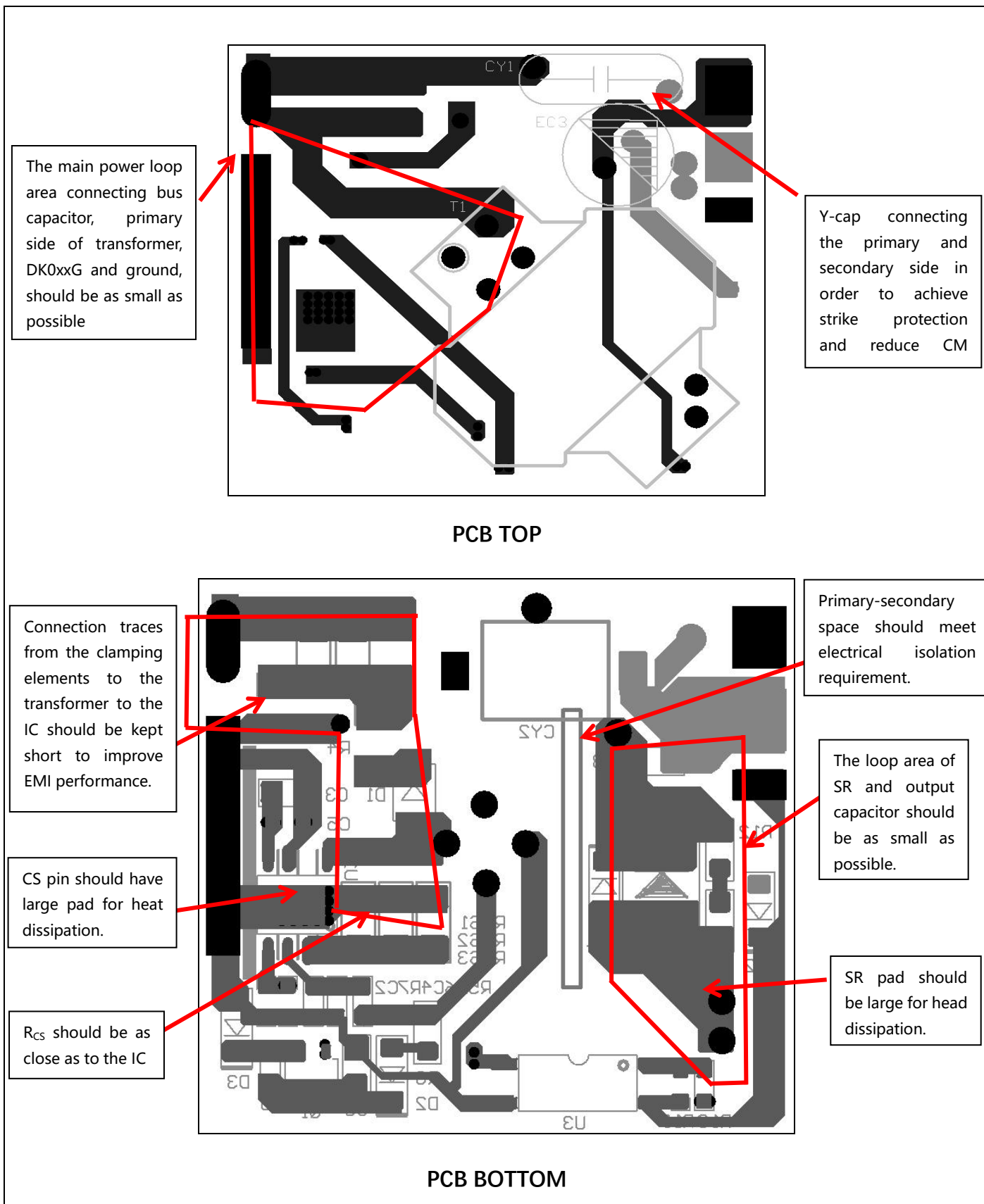


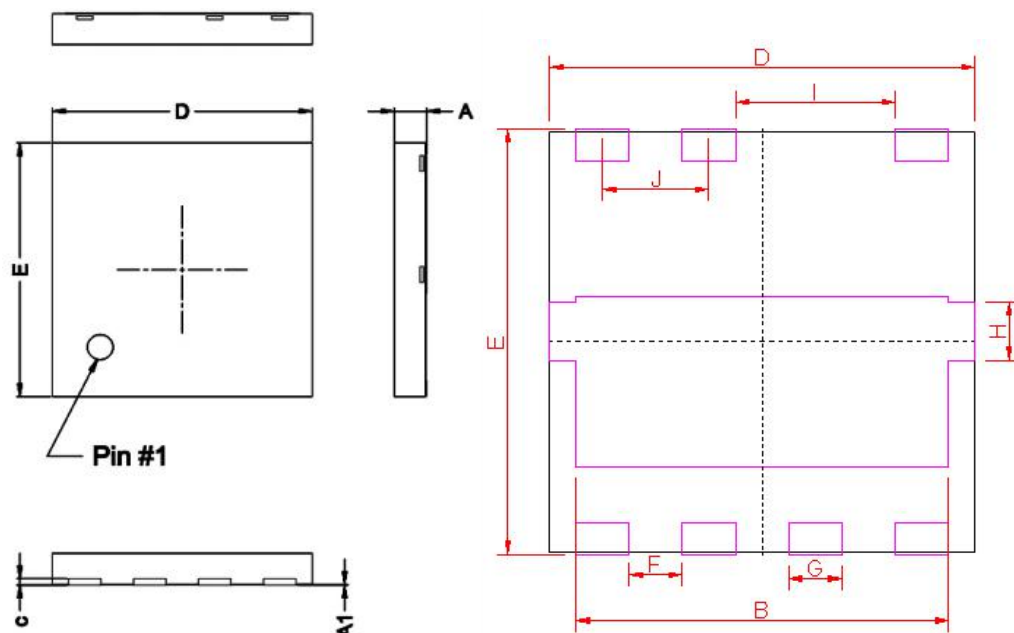
Figure.6 Valley Lock

PCB LAYOUT GUIDANCE



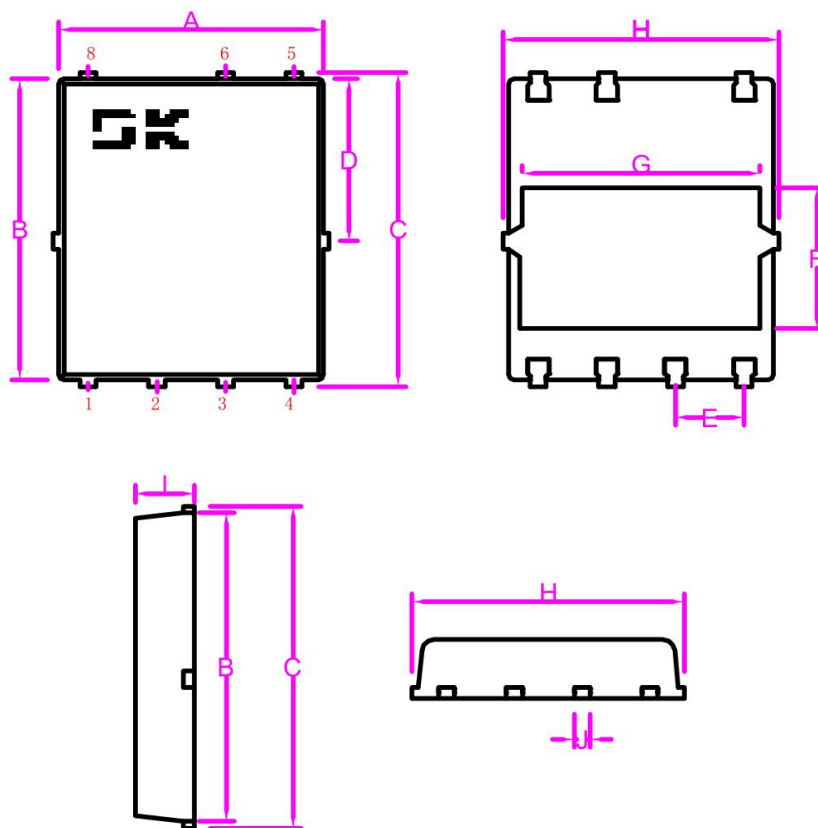
■ PACKAGE OUTLINE DIMENSIONS

◆ DFN8*8 (DK065G, DK075G)



Symbol	Dimensions in Millimeters		
	Min	NOM	Max
A	1.20	1.30	1.40
A1	0.00	-	0.05
B	6.95	7.00	7.10
C	0.50	0.55	0.60
D	8(NOM)		
E	8(NOM)		
F	0.98	1.00	1.02
G	0.98	1.00	1.02
H	1.08	1.10	1.12
I	2.95	3.00	3.05
J	2.00BSC		

◆ PDFN5*6 (DK012G/020G/025G/036G/045G)



Symbol	Dimensions in Millimeters		
	Min	NOM	Max
A	4.85	4.90	4.95
B	5.70	5.75	5.80
C	6.00	6.02	6.10
D	3.10 (NOM)		
E	1.27 BSC		
F	2.70 (NOM)		
G	4.4 (NOM)		
H	5.05	5.10	5.15
I	1.20	1.30	1.40
J	0.3 (NOM)		