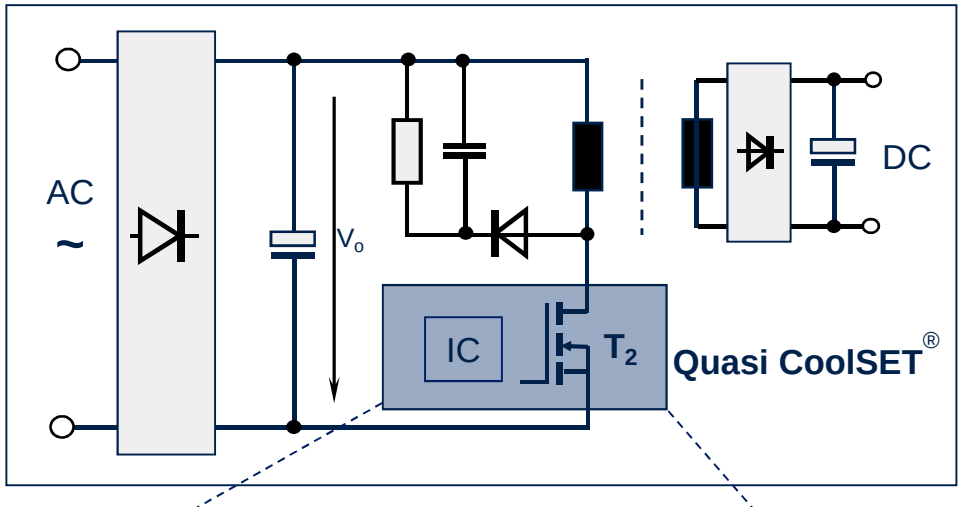
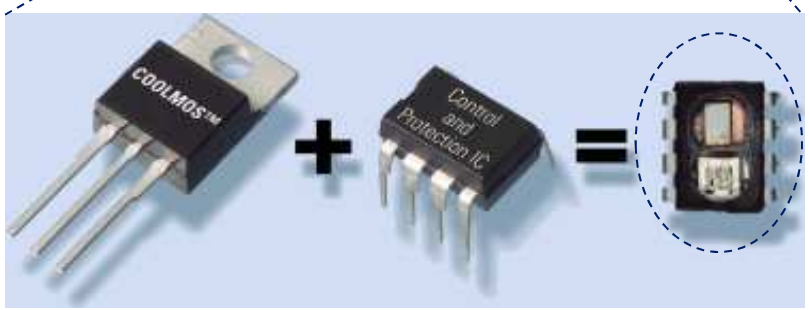
ENPC Workshop: **Auxiliary Power Supply Solution ---CoolSET™**

Yew Ming Lik
Business Development
ASIC & Power ICs
Infineon Technologies

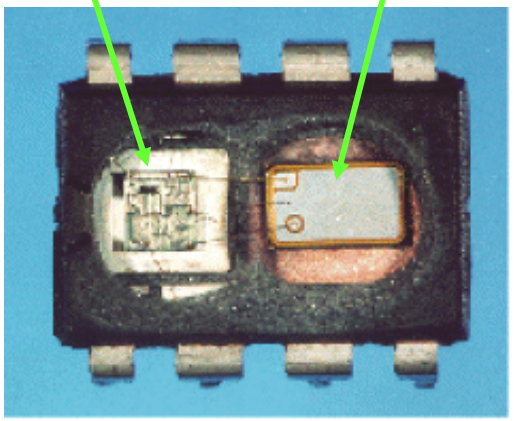
Never stop thinking

Infineon Integrated Power IC – F3 & Quasi. CoolSET®

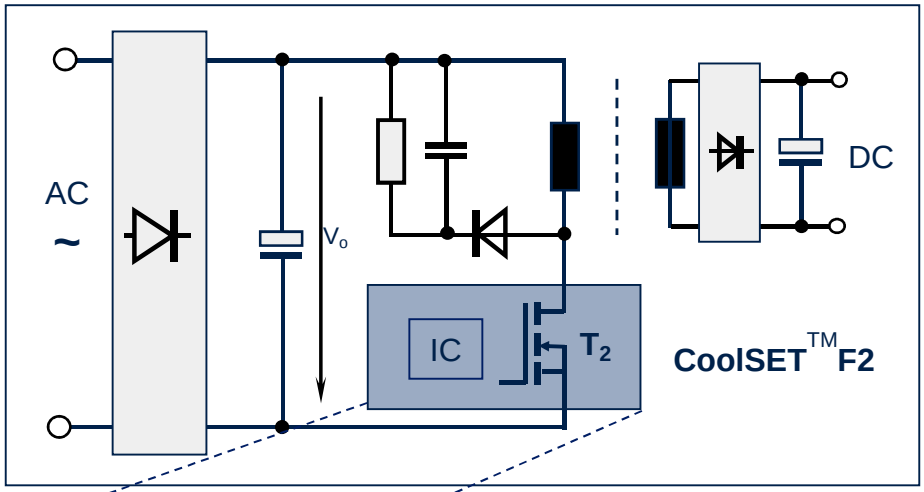




Quasi. PWM IC **CoolMOS**

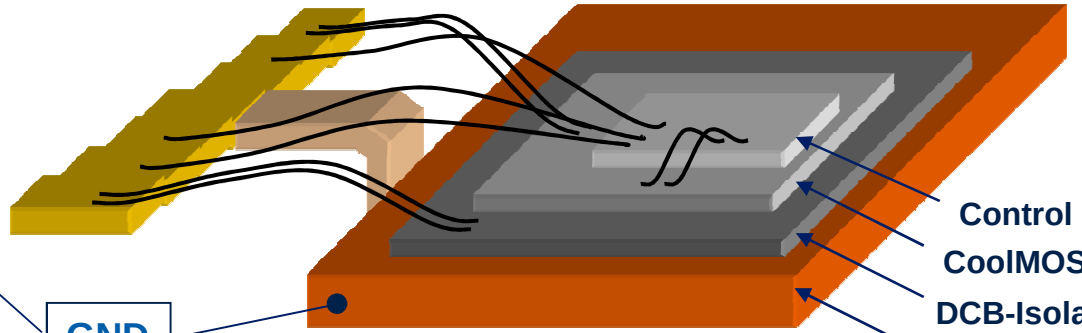


CoolSET™
Application - Isolated TO220-6 & Fullpak Package



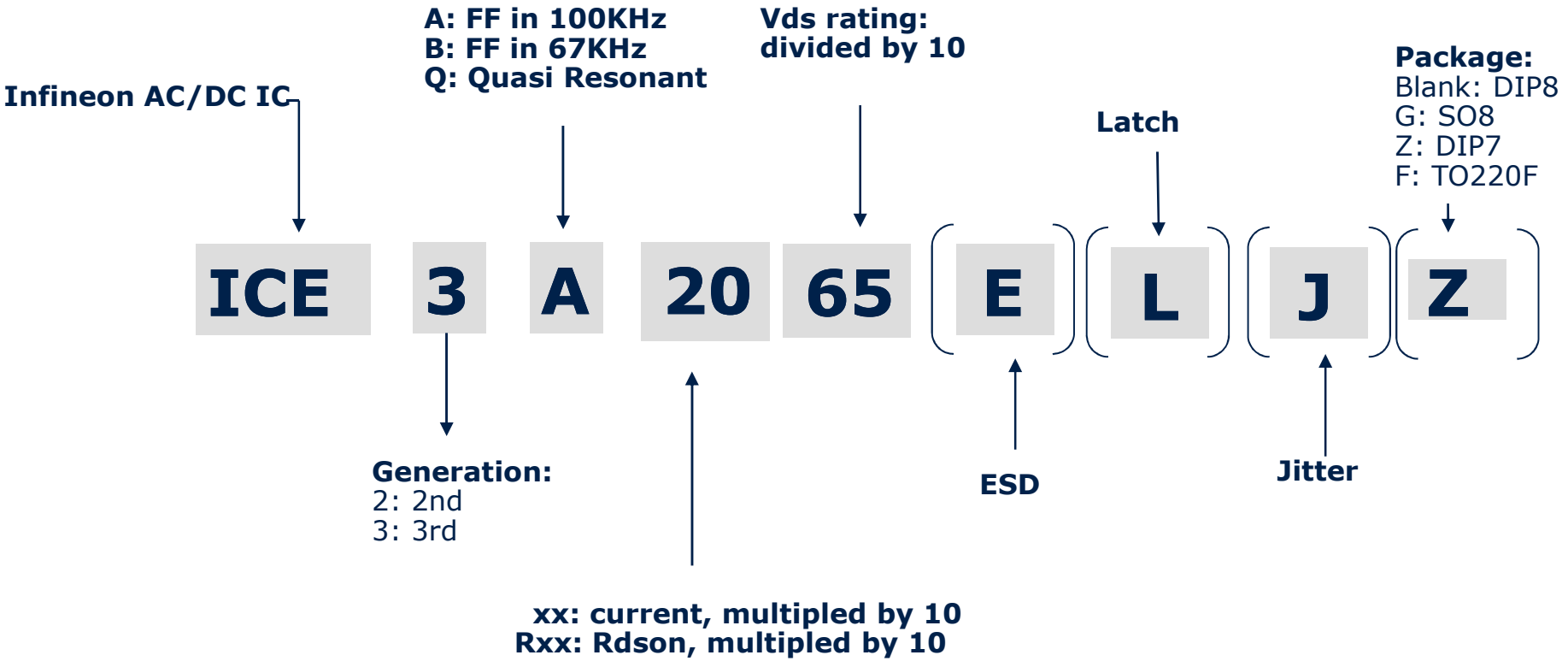
Typical SMPS topology for AC/DC conversion with CoolSET

Photo and schematic of CoolSET in TO-220-6 ISODRAIN package



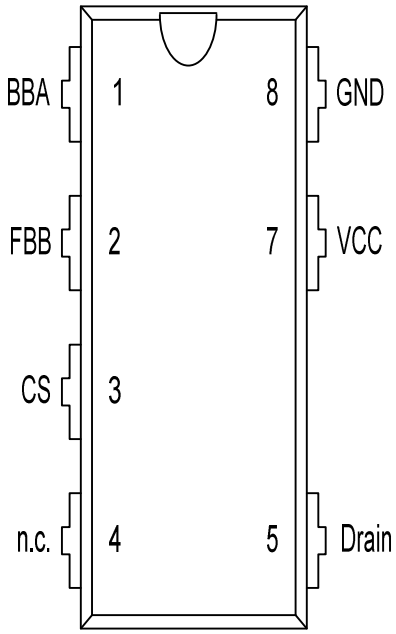
TO-220-6 ISOdrain
ISOLATED Package w. LOW Thermal Resistance

CoolSET Naming System



Fixed Switching CoolSET and Pin Assignment

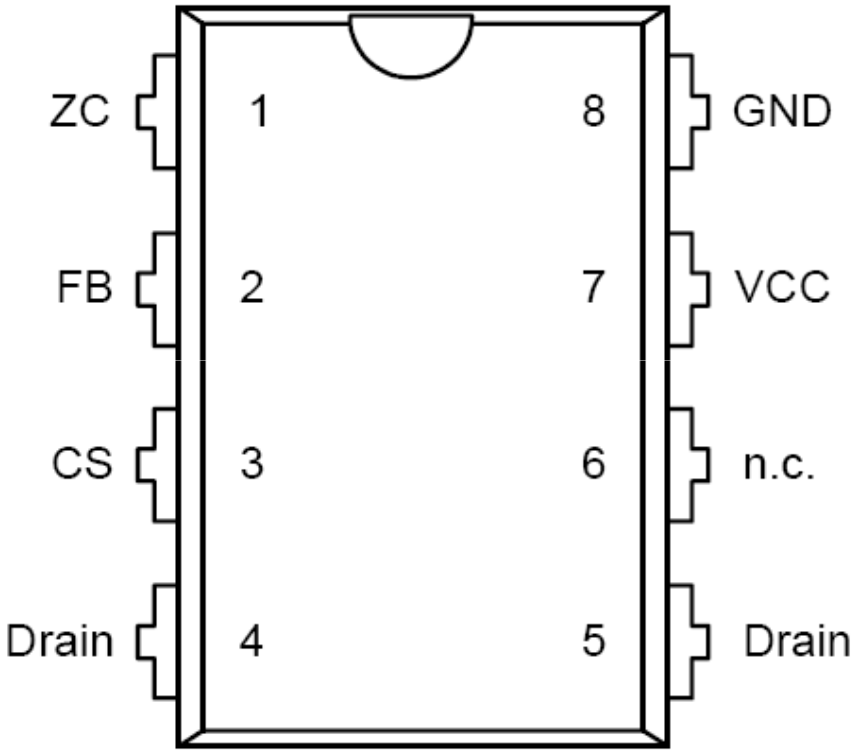
- Package : DIP-7 / DIP-8
- Pin assignment :



Pin	Name	Function
1	**BBA**	Brownout, extended Blanking time and external Auto-restart enable
2	**FBB**	FeedBack and Burst entry control
3	**CS**	Current Sense
4	**N.C.**	No Connection
5	**Drain**	Drain
6	**No pin**	No pin
7	**Vcc**	Vcc
8	**GND**	Ground

Quasi. CoolSET and Pin Assignment

Package PG_DIP-8



Pin	Symbol	Function
1	ZC	Zero Crossing
2	FB	Feedback
3	CS	Current Sense/ 650V[1] Depl. CoolMOS® Source
4, 5	Drain	650V[1] Depl. CoolMOS® Drain
6	n.c.	Not connected
7	VCC	Controller Supply Voltage
8	GND	Controller Ground

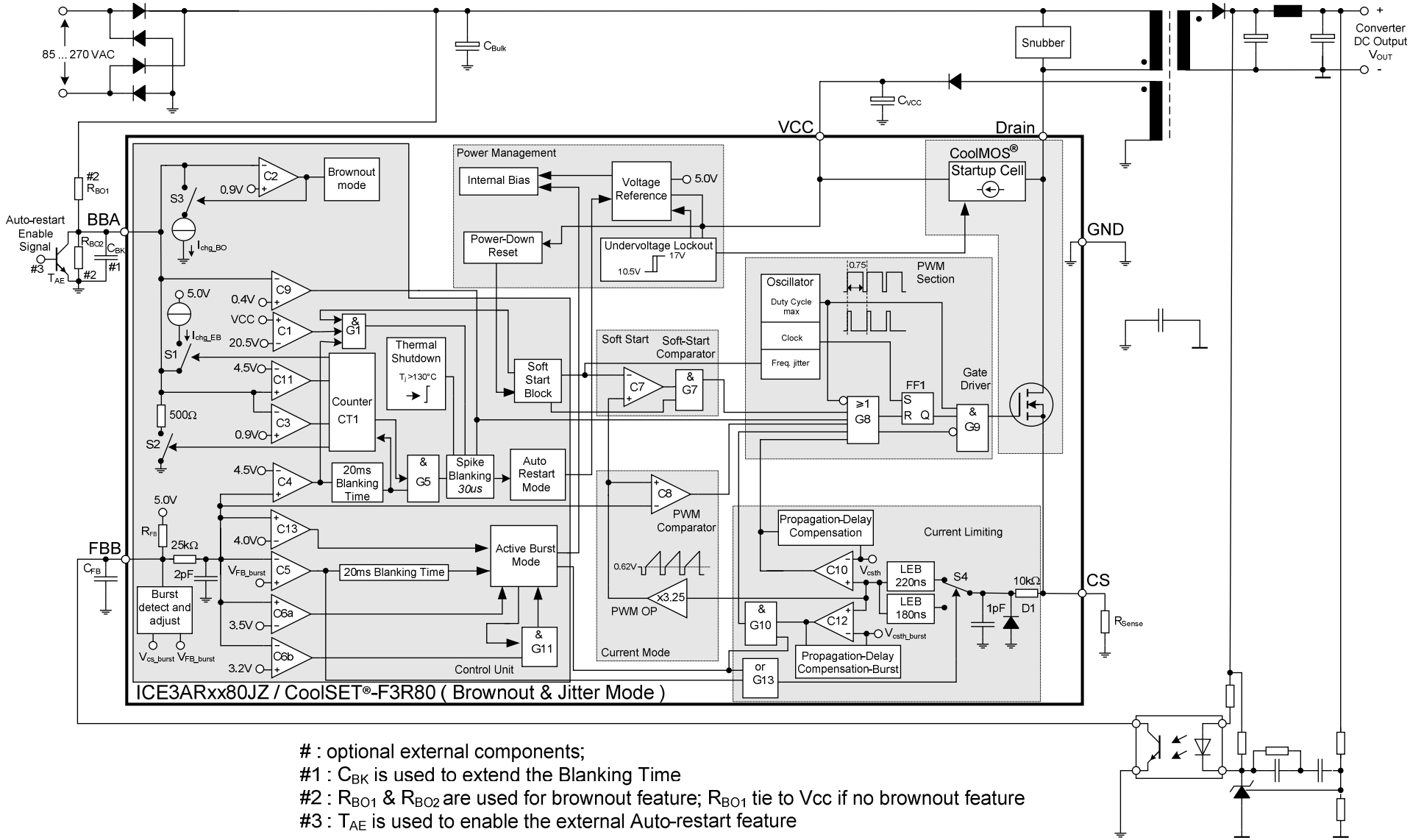
[1] at T_j=110°C

New features of ICE3A/BRXXXXJ Fixed Switching Frequency CoolSET

Based on F3R (ICE3BRxx65J) PWM controller core with 650V / 800V CoolMOS and startup cell. Additional features are as below.

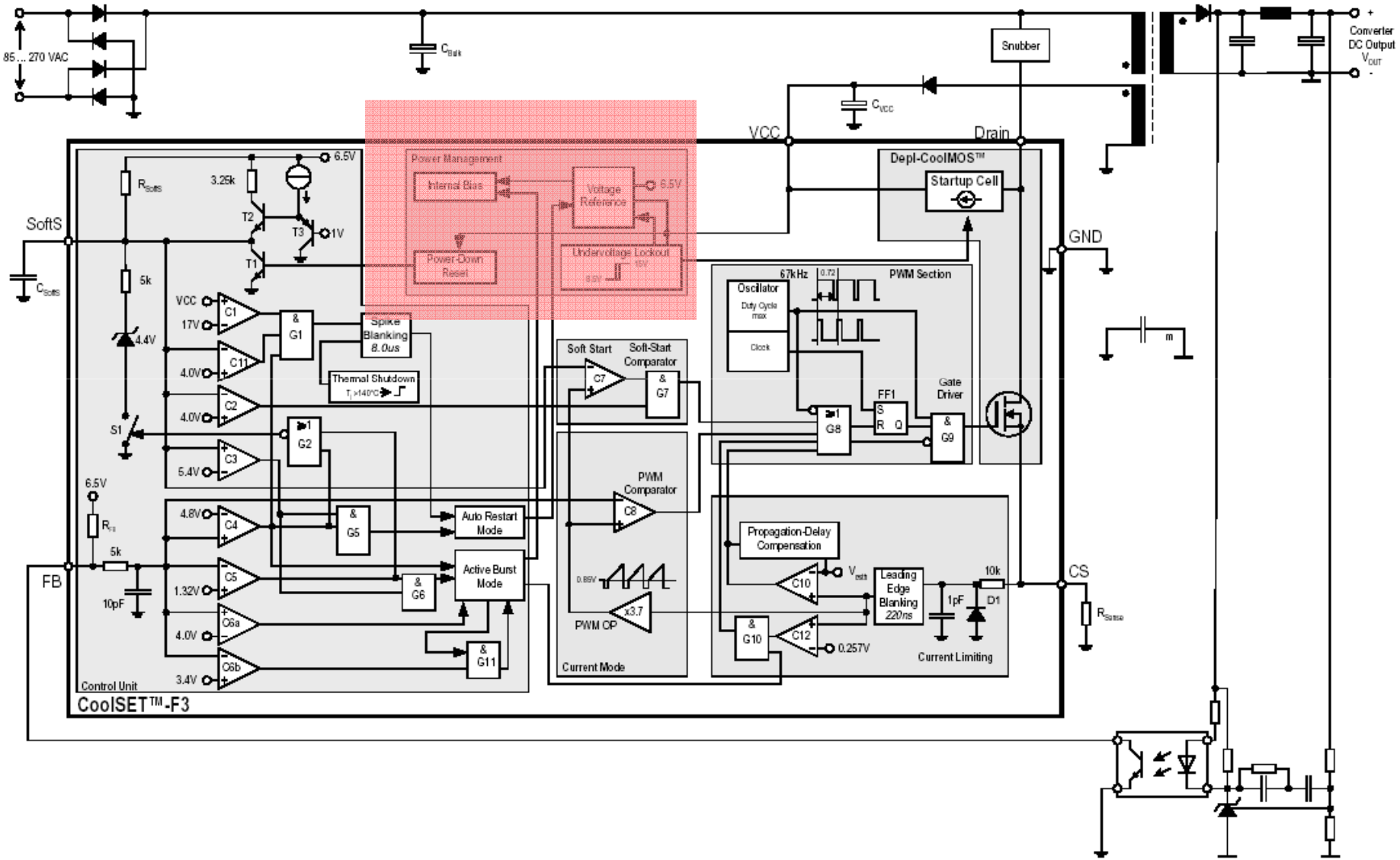
1. Brownout (800V CoolSET)
2. Enhanced Active Burst Mode
   - Selectable entry and exit of burst mode
   - Reduced output ripple during burst mode
   - Enhanced power control between low line and high line
3. New approach of the extended blanking time for OLP
4. Enhanced over temperature protection
5. Improved EMI performance

Block diagram of ICE3A/BRXXXXJ Fixed Switching Frequency CoolSET



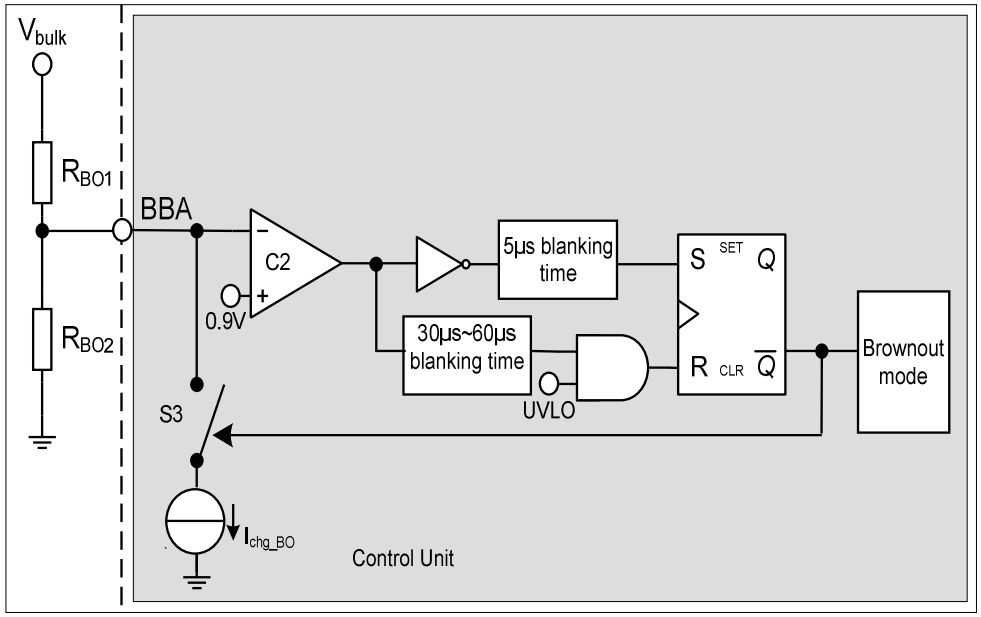
: optional external components;
#1 : C_{BK} is used to extend the Blanking Time
#2 : R_{BO1} & R_{BO2} are used for brownout feature; R_{BO1} tie to Vcc if no brownout feature
#3 : T_{AE} is used to enable the external Auto-restart feature

Main Feature : Integrated 650V / 800V Startup Cell



Key Features _ Brownout (800V CoolSET)

- Brownout feature is to control the system ON/OFF by detecting the input voltage such as bulk capacitor voltage; i.e. system off when the V_{bulk} is too low and system on when V_{bulk} goes back to normal level.
- The ON/OFF voltage can be adjusted by the 2 sensing resistors: R_{B01} and R_{B02}.



- The sensing resistors are calculated as below.

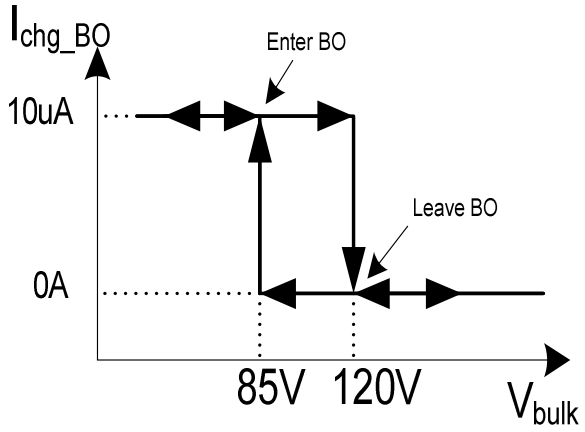
$$I_{chg\_BO} = 10uA,\ V_{ref} = 0.9V,$$

$$V_{BO\_hys} \rightarrow BO\_hysteresis,\ V_{BO\_l} \rightarrow BO\_low\_point,\ V_{BO\_h} \rightarrow BO\_high\_point$$

$$R_{BO1} = \frac{V_{BO\_hys}}{I_{chg\_BO}} \qquad R_{BO2} = V_{ref} \cdot \frac{R_{BO1}}{V_{BO\_l} - V_{ref}}$$

- For example :

V_{BO_h}	V_{BO_l}	V_{BO_hys}	R_{B01}	R_{B02}
120V	85V	35V	3.5MΩ	37.45kΩ
113V	99V	14V	1.4MΩ	12.84kΩ



Key Features _ Enhanced Active Burst Mode

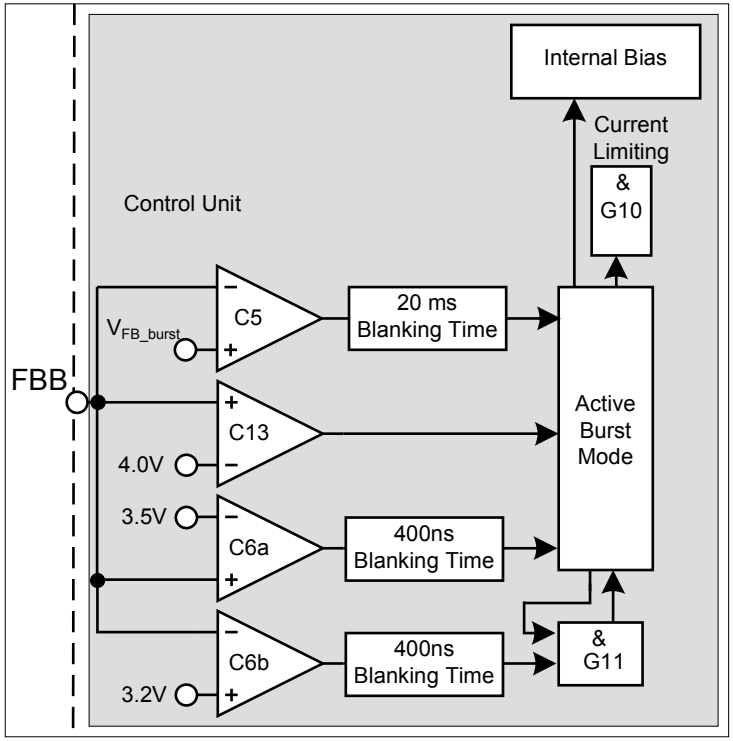
Conditions for enhanced Active Bust Mode (IFX patent)

- Enter burst mode :
  - $V_{FBB}<V_{FB\_burst}$ & 20ms blanking time

    (4 entry levels; V_{FB_burst} can be selected through the capacitor, C_{FB} at FeedBack pin)
- In the burst mode :
  - Burst "on" : 3.2V
  - Burst "off" : 3.5V
  - $V_{CS}=V_{CS\_burst}$
  - $V_{cc}>10.5V$ during burst mode

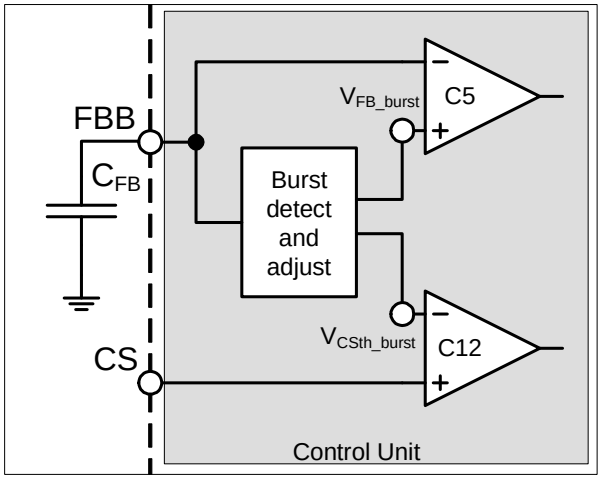
  (Output ripple is reduced because of the narrower delta burst "on" and "off" voltage)
- Leave burst mode:
  - $V_{FBB}>4V$

  (Propagation delay compensation is added during burst mode so that it has a good power control between high line and low line)



Key Features _ Enhanced Active Burst Mode (Cont'n)

- Entry burst mode selection
  - Entry burst mode level can be selected by adding different capacitor, C_{FB} at the FBB pin. The selected input power can be 10%, 6.67%, 3.33% and 0% of the maximum power (0% means no burst mode).
  - At the same time the exit burst mode power is set. They are 20%, 13.3%, 6.67% and 0% of the maximum power accordingly.



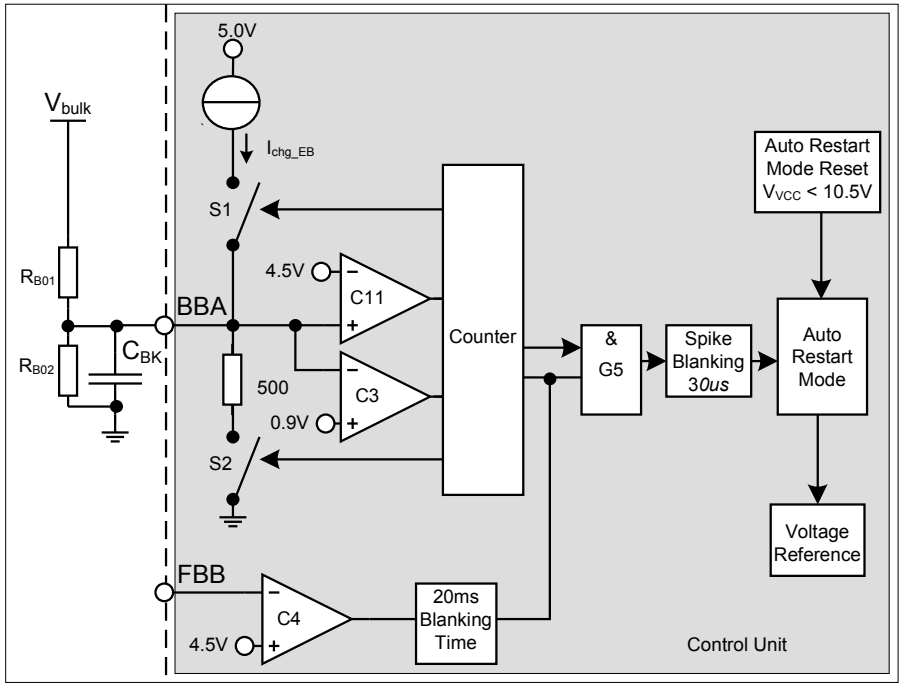
C_{FB}	typ.	Entry Level		Exit level	
		P_{in_entry} (% of P_{in_max})	V_{FB_burst}	P_{in_exit} (% of P_{in_max})	V_{CSth_burst}
≤100pF	COG	10%	1.6V	20%	0.45V
220pF~470pF	COG	6.67%	1.42V	13.30%	0.37V
1nF~2.2nF	COG	3.33%	1.18V	6.67%	0.26V
≥6.8nF	X7R ±10%	0	Never	0	Always

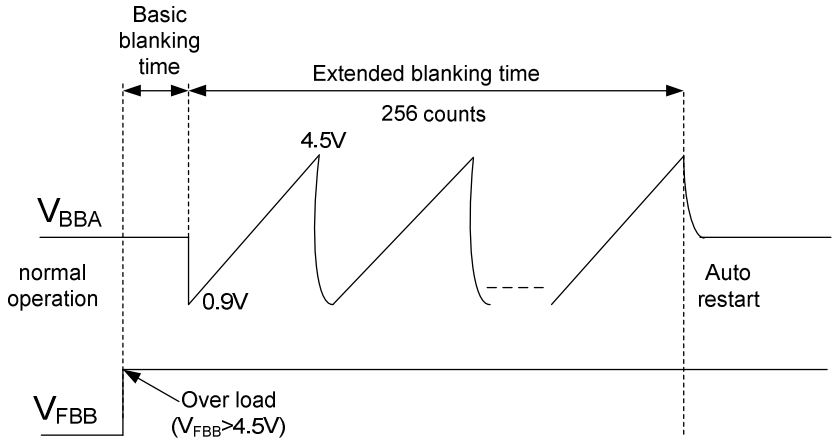
For example :

C_{FB}	P_{in_max}	$P_{in\_entry\_burst}$	$P_{in\_exit\_burst}$
100pF	30W	3W (10% P_{in})	6W (20% P_{in})
330pF	30W	2W (6.6% P_{in})	4W (13.3% P_{in})
1nF	30W	1W (3.3% P_{in})	2W (6.6% P_{in})
6.8nF	30W	Never	Always

Key Features _ Extended blanking time for OLP

- Overload protection : V_{FFB}>4.5V and after the blanking time, then goes to auto-restart mode.
- Blanking time : basic blanking time (20ms) + extended blanking time.
- New approach for extended blanking time as the same pin shared with 3 features; brownout, extended blanking time and auto-restart enable.
- Extended blanking time is achieved by charging C_{BK} from 0.9V to 4.5V by the I_{chg_EB} (0.6mA) and fast discharging to 0.9V through a 500Ω resistor and repeat for 256 times.



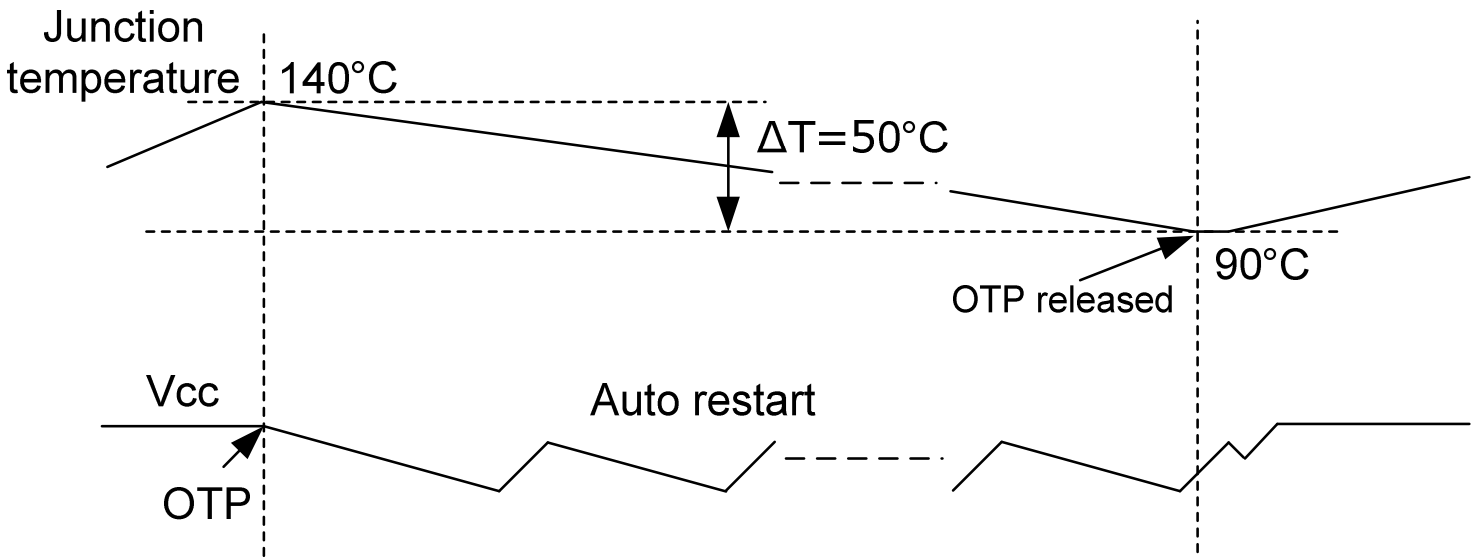


- For example :

C_{BK}	R_{BO2}	Extended blanking time
0.1uF	-	174ms
0.1uF	37.5KΩ	193ms
0.1uF	12.8KΩ	256ms

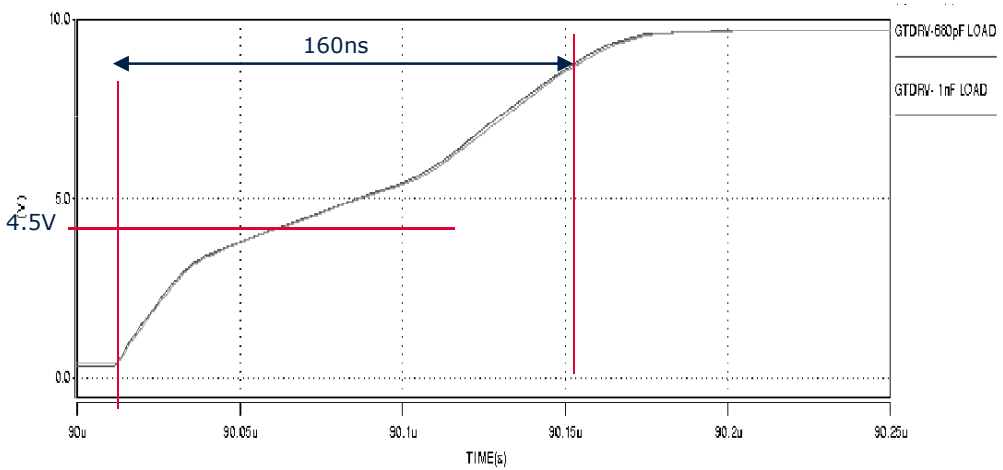
Key Features _ Enhanced over temperature protection

- Over temperature protection threshold is set at 140°C.
- After the OTP is triggered, the system will go into a non-switching auto restart mode. When the temperature is dropped to 90°C, the system restart again (temperature hysteresis is 50°C).



Key Features _ Improved EMI performance

- To improve the EMI performance, 3 features are implemented.
  - Frequency jittering : ±4KHz @ 4ms period
    - For conducted EMI
  - Modulated gate drive : increased modulation time to 160ns
    - For radiated EMI

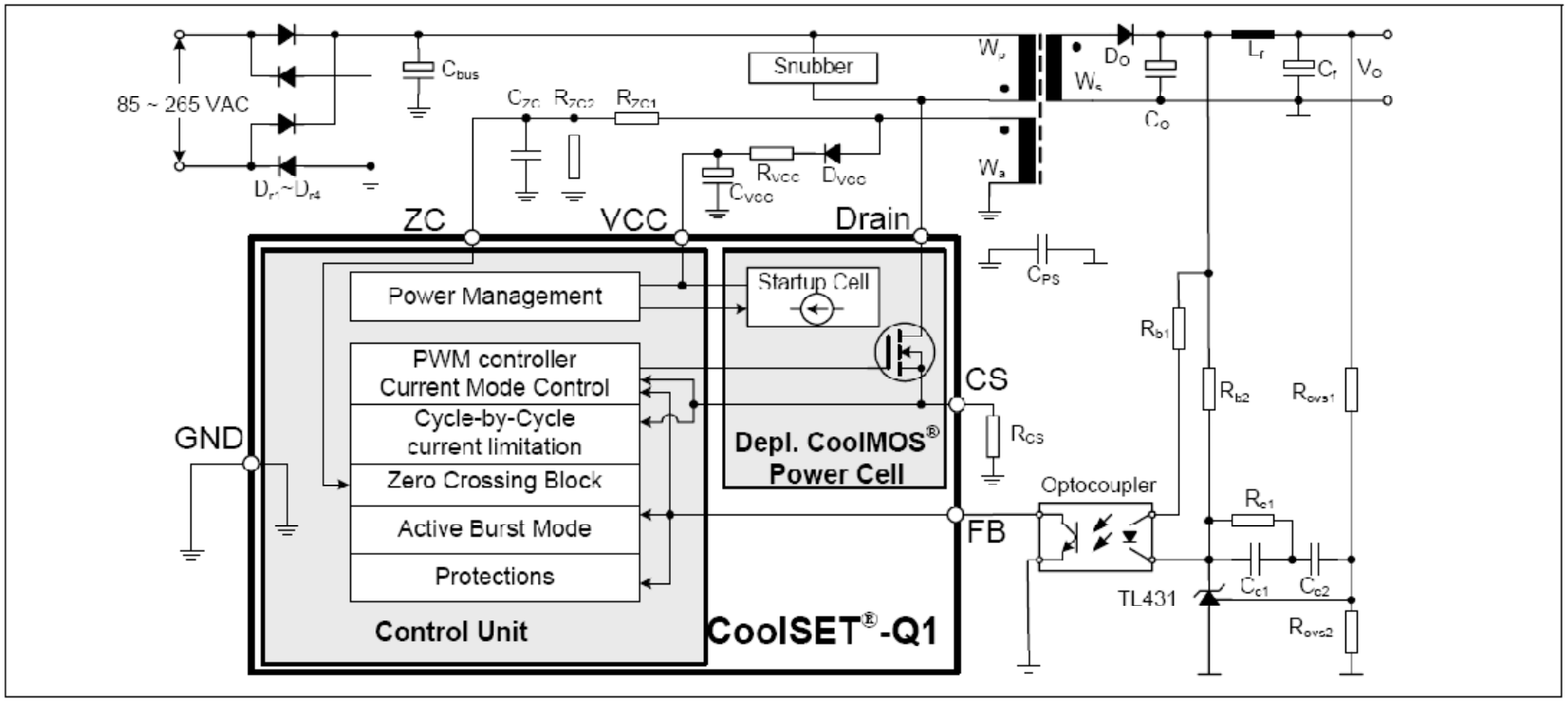


  - Gate drive resistor : added with 50Ω gate turn on resistor
    - For radiated EMI

Features Summary (Cont'n)

- DIP-7 package for larger creepage
- BiCMOS technology -- wider Vcc operating range
- 800V integrated Startup Cell--- no loss on startup circuit
- Enhanced Active Burst Mode for Lowest Standby Power with
  - Lower output ripple
  - Selectable enter burst level
- Brownout feature to provide robust ON/OFF control in application
- Built-in 10ms Soft start

Quasi. CoolSET Typical Application



Type	Package	Marking	V_{DS}	R_{DSon} [1]	230VAC ±15% [2]	85-265 VAC [2]
ICE2QR0665	PG-DIP-8-6	**ICE2QR0665**	650V	0.65	88W	50W

1) typ @ T=25°C

2) Calculated maximum input power rating at T_a=50°C, T_j=125°C and without copper area as heat sink.

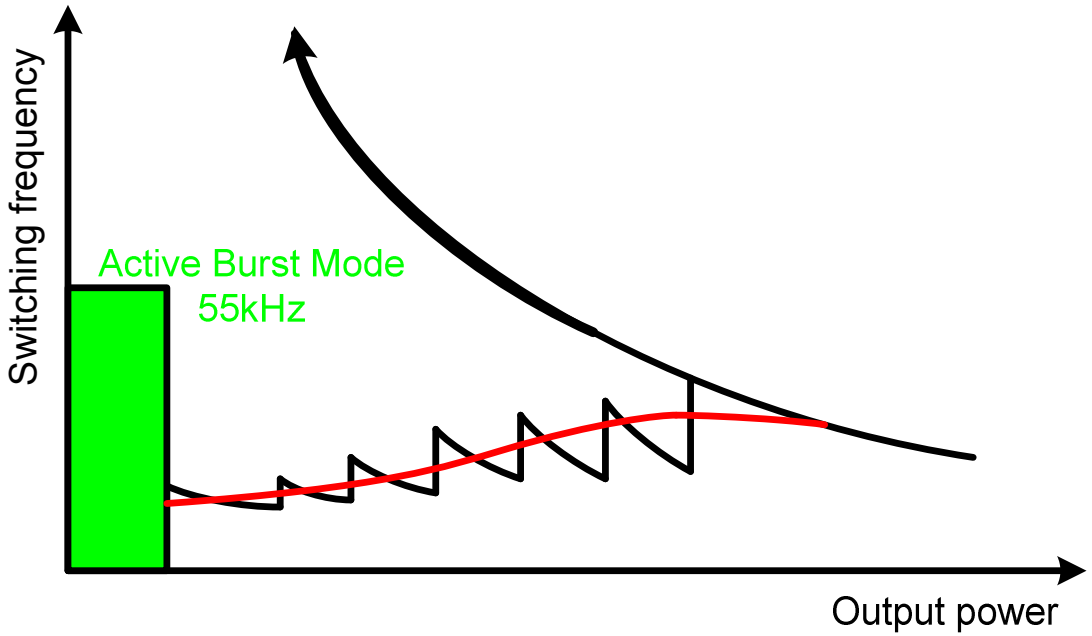
Quasi CoolSET Salient Features

- Only QR-CoolSET In Market offer 20~40W in DIP Package
- QR Plus Frequency Reduction Mode for Better Average Efficiency
- Valley Switching for Low Switching Loss and Good EMI
- Maximum Power limitation Due to Foldback Current Correction
- Very Low Standby Power Loss Due to Active Burst Mode

Features Summary

- Propagation delay compensation – accurate current limit between low line and high line
- Frequency jitter mode, soft gate driving and 50Ω gate turn on resistor – EMI performance
- Built-in 20ms and extendable Blanking Window for over load protection
- Over temperature protection with 50°C hysteresis
- Auto-Restart protection
  - Vcc Overvoltage, Over temperature, external auto restart enable, Overload, Open Loop, Vcc Undervoltage & Short Optocoupler

Quasi-resonant CoolSET@ Q2
Multi-mode operation



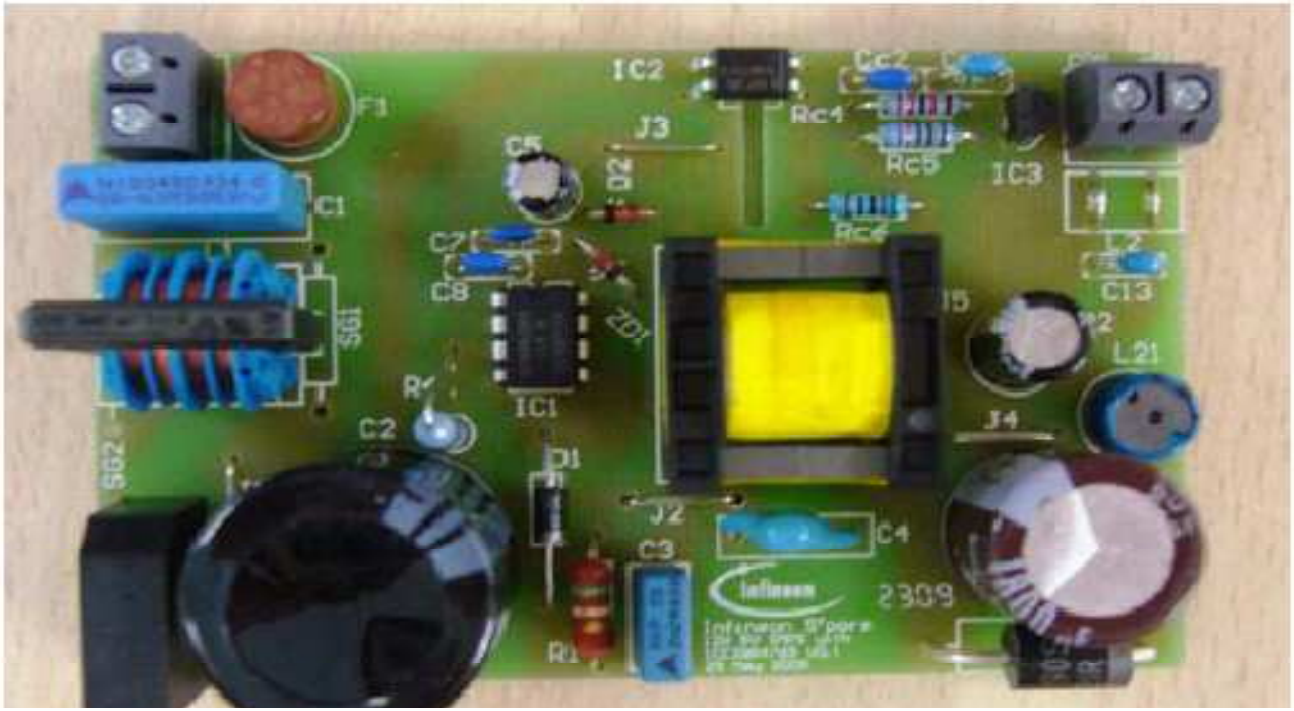
- The Quasi-CoolSET Q2 has a Digital Frequency Reduction at reduced output power
- MOSFET can be turned on at 1, 2 3 up to 7th zero crossing
- For light load, converter is operated at Active Burst Mode for power saving

Quasi. CoolSET Product Features

- 650V avalanche rugged CoolMOS® with built-in startup cell
- Quasiresonant operation till very low load
- Active burst mode operation for low standby input power (< 0.05W)
- Digital frequency reduction with decreasing load for reduced switching loss
- Built-in digital soft-start
- Foldback point correction and cycle-by-cycle peak current limitation
- Maximum on time limitation
- Auto restart mode for VCC Overvoltage and Undervoltage protections
- Auto restart mode for overload protection
- Auto restart mode for over temperature protection
- Latch-off mode for adjustable output overvoltage protection and transformer short-winding protection

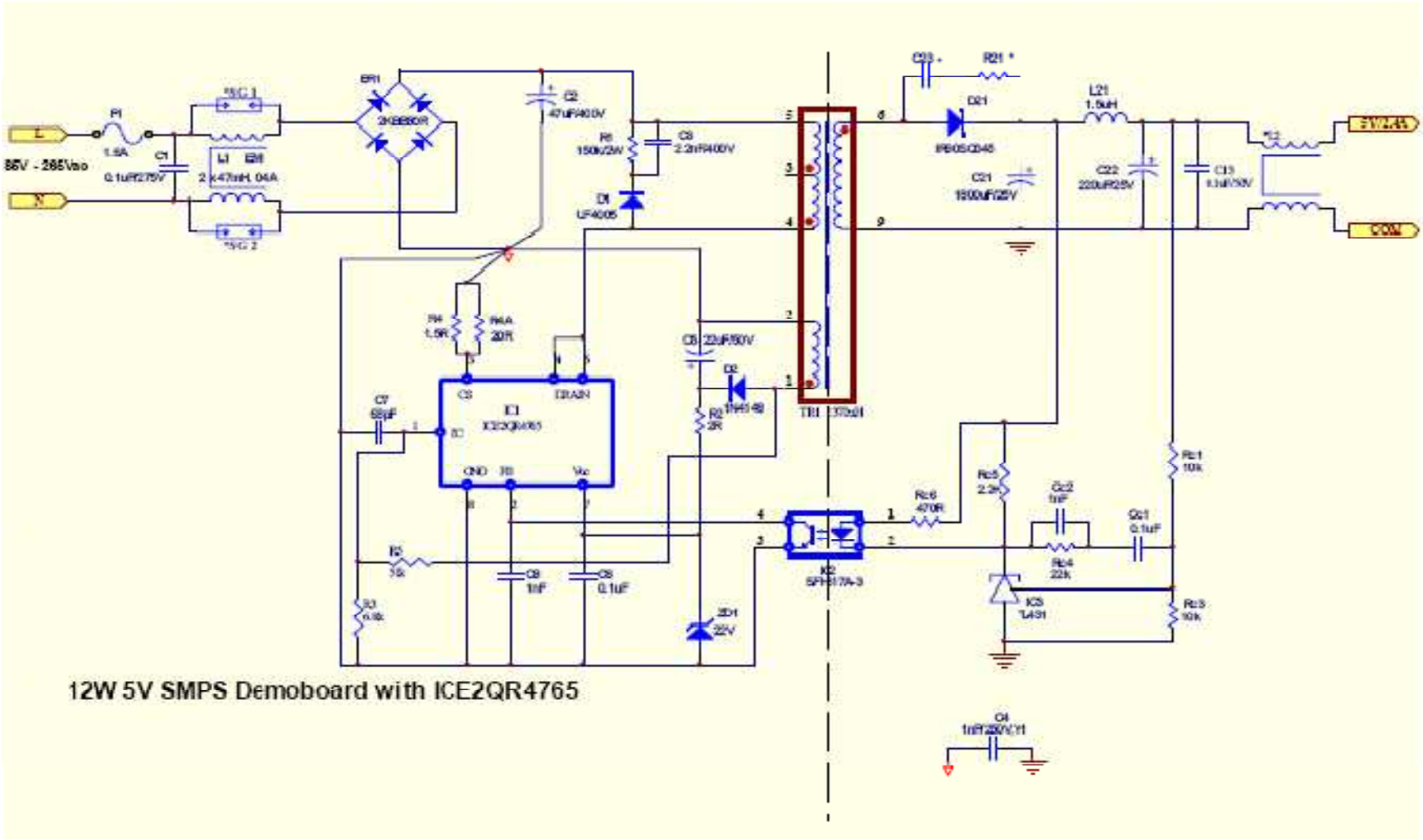
12W 5V Evaluation board with ICE2QR4765

Evaluation Board

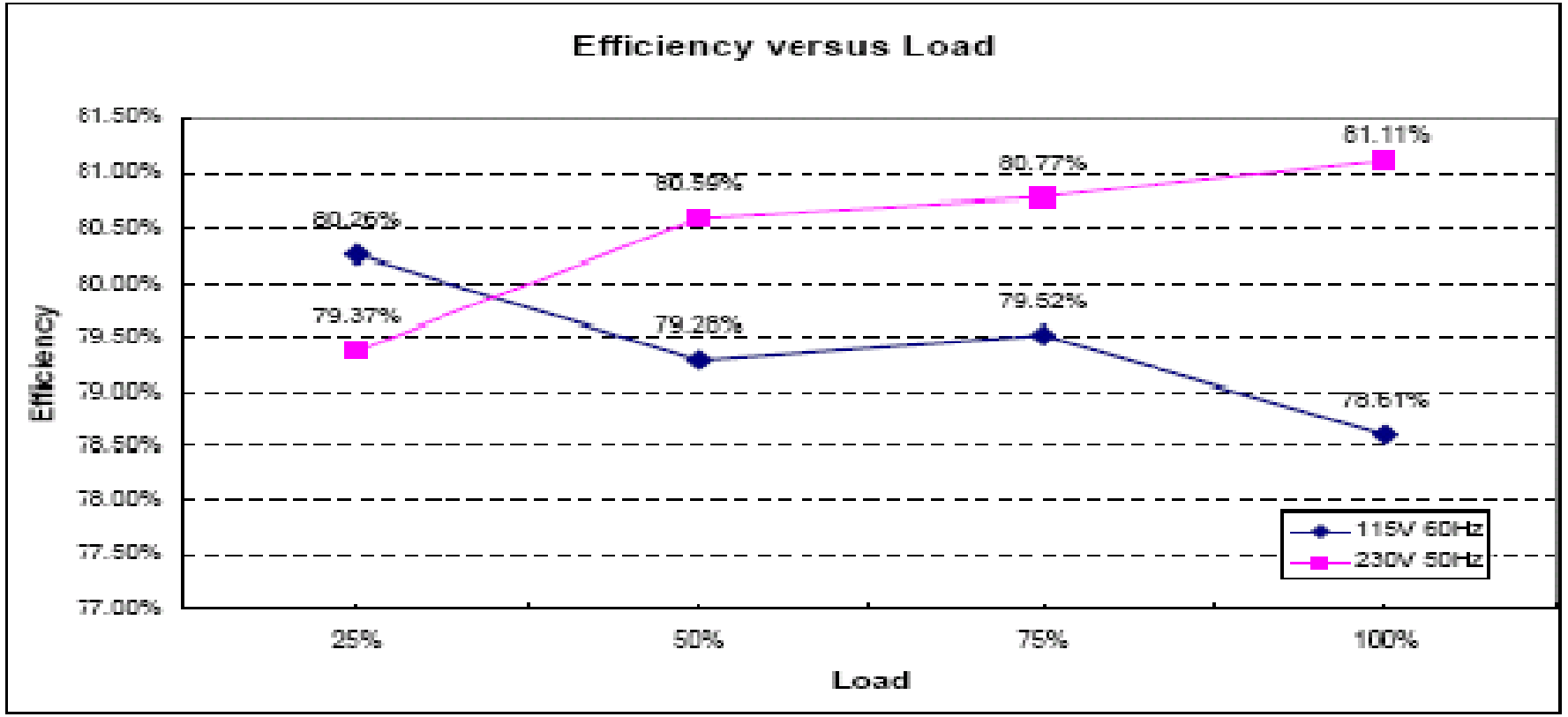


Input voltage	85Vac~265Vac
Input frequency	50Hz, 60Hz
Output voltage and current	5V 2.4A
Output power	12W
Efficiency	>78% at full load
Standby power	<100mW@no load
Minimum switching frequency at full load, minimum input voltage	65kHz

12W 5V Evaluation Board with ICE2QR4765 : Circuit diagram

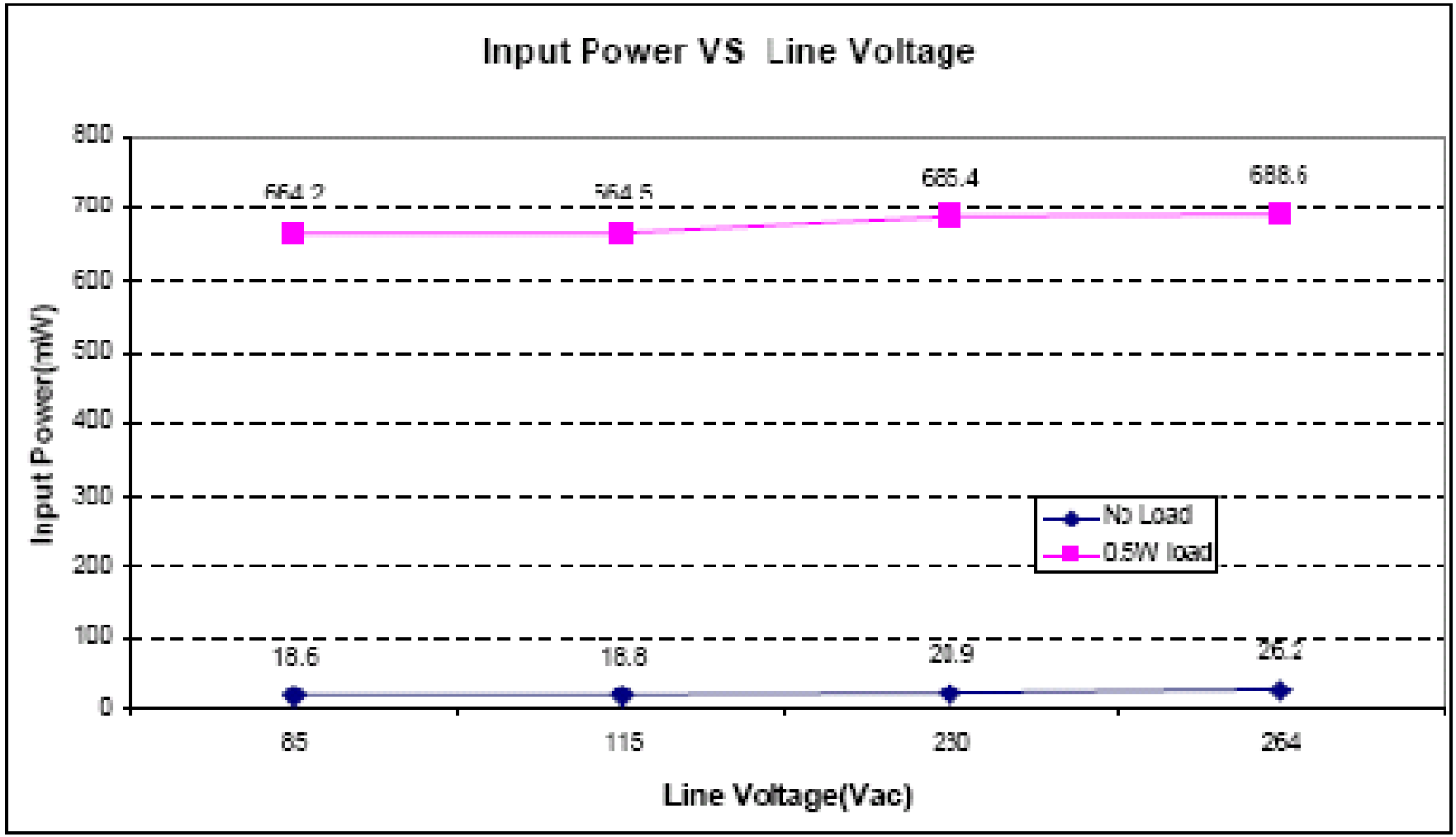


12W 5V Evaluation Board with ICE2QR4765 : Efficiency Vs Load

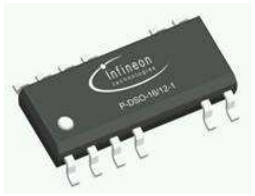


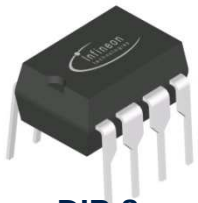
Input voltage(Vac)	Input power(W)	Vo(V)	Io(A)	Po(W)	Efficiency
115	3.7367	4.9983	0.6	2.99898	80.26%
115	7.5648	4.9978	1.2	5.99736	79.28%
115	11.3124	4.9973	1.8	8.99514	79.52%
115	15.2544	4.9966	2.4	11.99184	78.61%
230	3.7785	4.9983	0.6	2.99898	79.37%
230	7.4424	4.9979	1.2	5.99748	80.59%
230	11.1366	4.9975	1.8	8.9955	80.77%
230	14.7858	4.9971	2.4	11.99304	81.11%

12W 5V Evaluation Board with ICE2QR4765 : Standby Power Vs AC Input Voltage

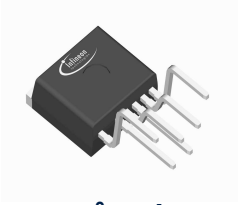


CoolSET™ F3
Product Overview





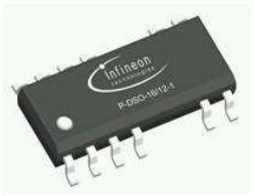
- A version: f = 100kHz
- B version: f = 67 kHz

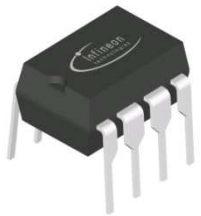


ISODrain
- Isolated
- low R_{th}

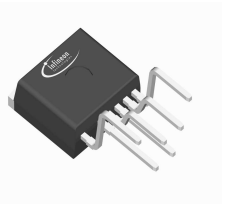
R_{DSon}	SO-16	DIP-8	POUTmax	TO-220-6	I²-Pak	POUTmax
6.5Ω	ICE3B0365JG	ICE3A0365 ICE3B0365J	9W/17W			
4,7Ω	ICE3B0565JG	ICE3A0565 ICE3B0565J	12W/21W			
3,0Ω		ICE3A1065 ICE3B1065	15W /25W	ICE3A2065P ICE3B2065P ICE3A3065P ICE3B3065P	ICE3A2065I ICE3B2065I ICE3A3065I ICE3B3065I	55W/90W 68W/125W
2,1Ω						
1,7Ω		ICE3B1565J ICE3A1565 ICE3B1565	20W/32W			
1,5Ω				ICE3A3565P ICE3B3565P ICE3A5065P ICE3B5065P ICE3A5565P ICE3B5565P	ICE3A3565I ICE3B3565I ICE3A5065I ICE3B5065I ICE3A5565I ICE3B5565I	
0,95Ω		ICE3A2065 ICE3B2065	27W/41W			80W/144W
0,8Ω						100W/180W
0,65Ω		ICE3A2565 ICE3B2565	31W /46W			110W/200W

CoolSET™ F3R & 2QR Product Overview





- A version: f = 100kHz
- B version: f = 67 kHz
- Quasiresonant



Fullpak
- Isolated
- low R_{th}

R_{DSon}	SO-16	DIP-7/8	P_{OUTmax}	R_{DSon}	TO-220-6	P_{OUTmax}
10.0Ω			9W/17W	2,5Ω	ICE3BR2565JF	55W/90W
4,7Ω	ICE3B4765JG	ICE3BR4765J ICE2QR4765 ICE3AR4780JZ ICE2QR4780Z	12W/21W			
2,2Ω		ICE3AR2280JZ ICE3BR2280JZ ICE2QR2280Z	15W/28W	1,5Ω	ICE3BR1565JF	68W/125W
1,7Ω		ICE3BR1765J ICE2QR1765	20W/32W	1,0Ω	ICE3BR1065JF	80W/144W
0,65Ω	ICE2QR0665G	ICE3BR0665J ICE2QR0665 ICE3AR0680JZ ICE3BR0680JZ ICE2QR0680Z	31W /46W	0,65Ω	ICE3BR0665JF	110W/200W

SMPS IC's at a glance
Focus Product Portfolio

FF CoolSET	ICE3BR4765J	ICE3BR1765J	ICE3BR0665J			
	ICE3BR4765JZ	ICE3BR1765JZ	ICE3BR0665JZ			
	ICE3BR4765JG					
	ICE3BR2565JF	ICE3BR1565JF	ICE3BR1065JF	ICE3BR0665JF		
	ICE3A1065ELJ	ICE3A2065ELJ				
	ICE3AR4780JZ	ICE3AR2280JZ	ICE3AR0680JZ			
FF PWM IC	ICE3BS03LJG	ICE3AS03LJG				
QR CoolSET	ICE2QR4765	ICE2QR1765	ICE2QR0665			
QR PWM IC	ICE2QS01	ICE2QS02G	ICE2QS03	ICE2QS03G		
Res LLC HB	ICE1HS01G	ICE2HS01G				
CCM PFC IC	ICE2PCS01	ICE2PCS02	ICE2PCS03	ICE2PCS04	ICE2PCS05	ICE2PCS06
	ICE2PCS01G	ICE2PCS02G	ICE2PCS03G	ICE2PCS04G	ICE2PCS05G	ICE2PCS06G
	ICE3PCS01G	ICE3PCS02G	ICE3PCS03G			
PFC+TTF	ICE1CS02	ICE1CS02G				

Never stop thinking