Current resonant control IC FA6B20N

Datasheet

1. Overview

FA6B20N is a switching power supply control IC for LLC current resonant converter.

It incorporates a 600V start up circuit, downsizing the circuit and enabling low-power consumption. It also incorporates a 600V high-side driver and low side driver, which can drive directly both high-side and low-side MOSFETs with 50% duty cycle alternatively.

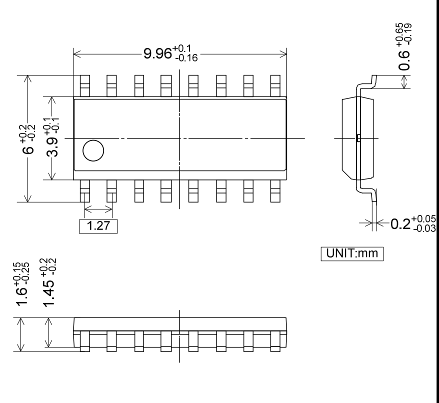
To ensure high reliability of the power supply, the capacitive mode prevention function, high-accuracy overload protection function and overcurrent protection function with adjustable delay time are provided. In addition, efficiency at light load is improved with low standby mode, therefore auxiliary power supply for standby can be removed.

When it is used with Fuji CRM PFC control IC “FA1A60N”, FA6B20N controls PFC IC operating mode (continuous, burst or stop operation). It helps to improve efficiency of PSU, optimize the PFC operation and reduce external components.

Since a small package of 16 pins is used and the number of exterior parts is substantially reduced, space- and cost-saving power supply can be obtained.

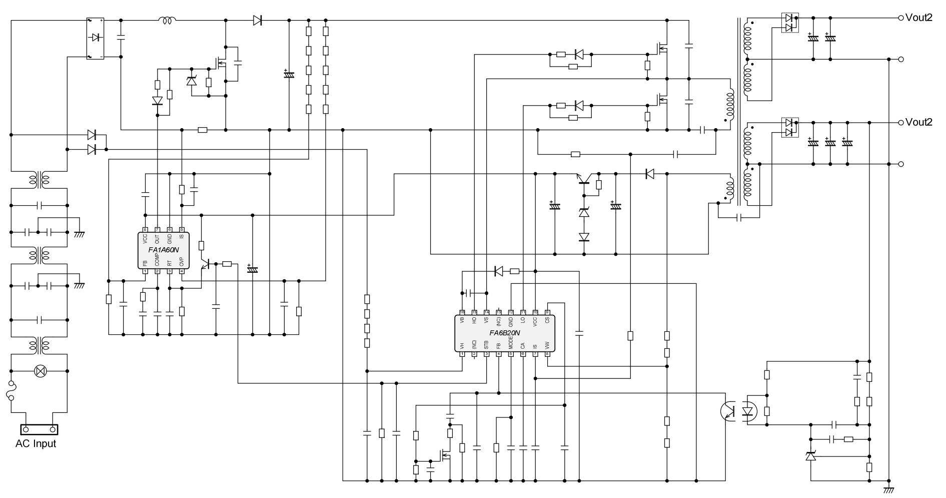
2. Features

- The integrated startup circuit achieves downsized power supply and lower power consumption.
- Operating mode can be switched between normal operation mode and low standby mode.
- ”Auto standby operation” and “Standby operation by external signal” are selectable.
- During the low standby mode, standby power is lowered by the burst mode operation.
- Integrated input filter X-capacitor discharge function decreases loss due to discharge resistance.
- Low consumption current, 0.80mA (Vcc quiescent current).
- Integrated high-side and low-side drive circuits, which can be directly connected to the power MOSFET and operates with 50% duty cycle.
- Since the dead time is set automatically within the IC, capacitive mode and hard switching are prevented.
- Various protection functions: overcurrent (IS pin), overload (CA,FB pin), overvoltage (VCC pin), overheat and protection by external signal (MODE pin).
- Integrated level-fixed brown-in/out function (VH pin)
- Various mode selection settings can be made: overcurrent protection (detection by IS pin) delay time setting, operation setting in standby mode, and adjusting output power switching to standby mode.
- Under voltage lock out function (VCC,VB pin)
- Package: SOP-16 (compliant with JEDEC)

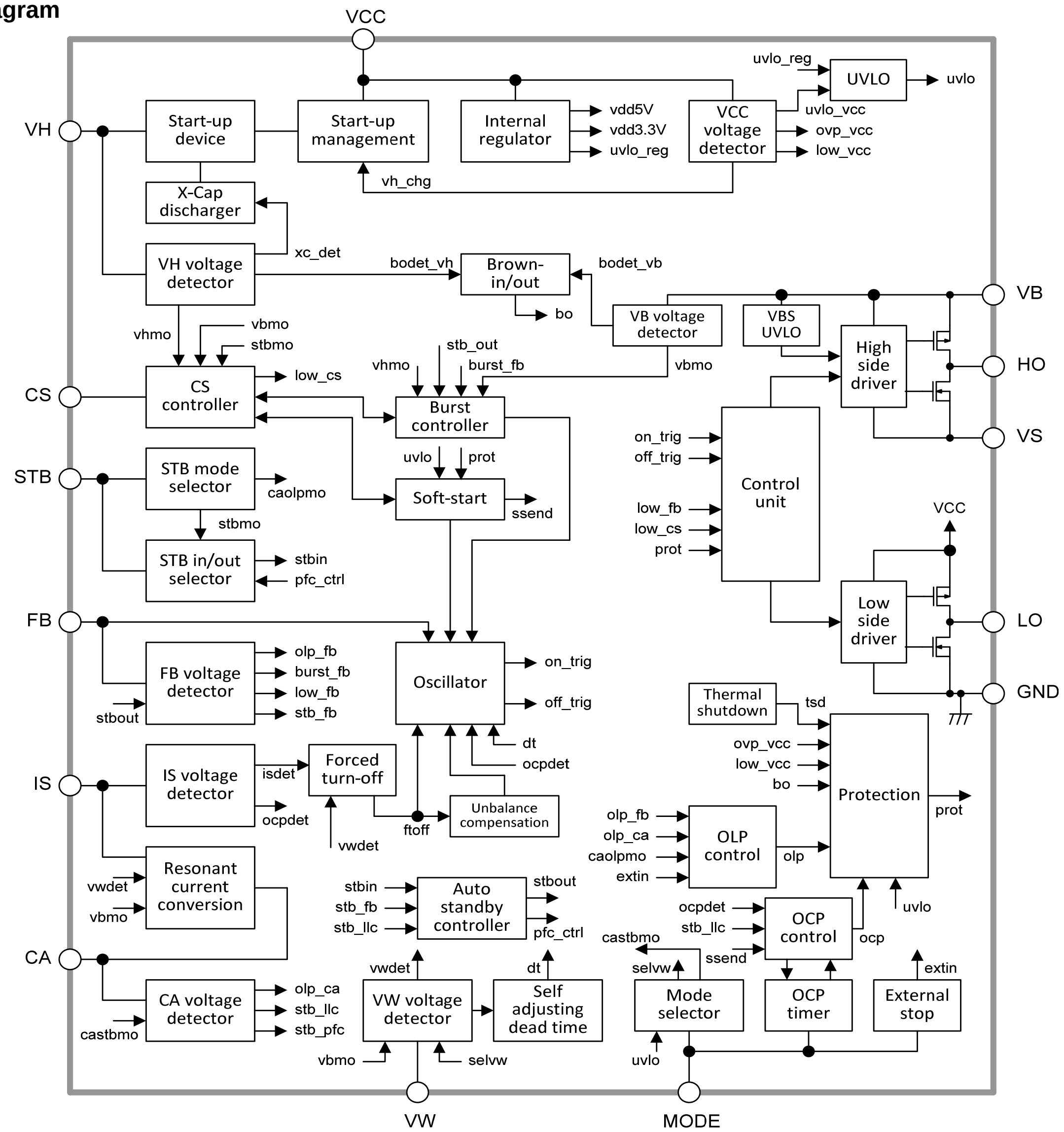


Package：SOP-16

3. Application circuit example (FA1A60N,FA6B20N)



4. Block diagram



5. Functional description of pins

Pin No.	Pin name	I/O	Description	Note
1	VH	I	High voltage input	*2
2	(NC)	-	(No connection)	*3
3	STB	I/O	Standby signal input and output PFC interconnection	*1, *2
4	FB	I/O	Feedback input	*1, *2
5	MODE	I/O	Operating mode setting and delay time setting for over current protection	*1, *2
6	CA	O	Input power sensing capacitor	*1, *2
7	IS	I	Resonant current detection	*1, *2
8	VW	I	Winding voltage detection	*1, *2
9	CS	I/O	Soft-start and burst operation setting input and output	*1
10	VCC	I/O	Power supply	*1
11	LO	O	Low side gate driver output	*2
12	GND	-	Ground	-
13	(NC)	-	(No connection)	*3
14	VS	I	High-side floating ground	-
15	HO	O	High-side gate driver output	*2
16	VB	I	High-side floating power supply	*1

*1: Connect capacitor
*2: Connect resistor
*3: Pin 2 and 13 are high voltage spacer and these pins are not internally connected.

6. Ratings & characteristics

"-" shows source and "+" shows sink in current descriptions.

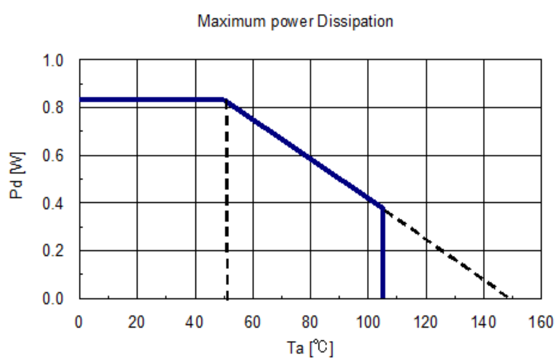
1) Absolute maximum ratings

Stress exceeding absolute maximum ratings may malfunction or damage the device.

Pin name	Item	Symbol	Value	Unit
VB	High side floating absolute voltage	V_B	-0.3 to 630	V
VB	High side floating absolute current in no switching	I_{VB}	0.1	mA
VS	High side floating supply offset voltage	V_S	V_B-30 to V_B+0.3	V
VS	High side floating supply offset current in no switching	I_{VS}	0.1	mA
VB,VS	High side floating supply voltage ($V_{BS}=V_B-V_S$)	V_{BS}	-0.3 to 30	V
VB,VS	High side floating supply current in no switching	I_{BS}	1.5	mA
HO	High side floating output pin voltage	V_{HO}	V_S-0.3 to V_B+0.3	V
HO	High side floating output pin current *1 (V_B-V_S=30V, Pulse Width < 1us, 1pulse)	I_{HO}	-0.8/ 1.8	A
VCC	Low side supply voltage	V_{CC}	-0.3 to 33	V
VCC	Low side supply voltage in no switching	I_{CC}	3.0	mA
LO	Low side output pin voltage	V_{LO}	-0.3 to V_{CC}+0.3	V
LO	Low side output pin current *1 (V_{CC}=30V, Pulse Width < 1us, 1pulse)	I_{LO}	-0.8/ 1.5	A
VS	Allowable offset supply voltage transient dv/dt	dV_S/dt	-50 to 50	kV/us
VS	Minus surge voltage (Pulse width=0.5us, V_{BS}=10V, V_{CC}=12V)	$-V_S$	-30	V
VH	VH pin input voltage	V_H	-0.3 to 600	V
VH	VH pin input current	I_{VH}	18	mA
STB	STB pin input voltage	V_{STB}	-0.3 to 5.3	V
STB	STB pin input current	I_{STB}	-200 to 100	uA
FB	FB pin input voltage	V_{FB}	-0.3 to 5.3	V
FB	FB pin input current	I_{FB}	-100 to 100	uA
MODE	MODE pin input voltage	V_{MODE}	-0.3 to 5.3	V
MODE	MODE pin input current	I_{MODE}	-200 to 100	uA
CA	CA pin input voltage	V_{CA}	-0.3 to 5.3	V
CA	CA pin input current	I_{CA}	-100 to 100	uA
IS	IS pin input voltage	V_{IS}	-5.3 to 5.3	V
IS	IS pin input current	I_{IS}	-150 to 150	uA
VW	VW pin input voltage	V_{VW}	-5.3 to 5.3	V
VW	VW pin input current	I_{VW}	-150 to 150	uA
CS	CS pin voltage	V_{CS}	-0.3 to 5.3	V
CS	CS pin current	I_{CS}	-100 to 100	uA
—	Power dissipation (T_a=25˚C)	P_d	0.83	W
—	Thermal resistance, junction to ambient *2	R_{thJA}	120	˚C/W
—	Operating junction temperature	T_j	-40 to 150	˚C
—	Storage temperature	T_{stg}	-40 to 150	˚C

*1 . Please consider power supply voltage and load current well and use this IC within maximum power dissipation, operating junction temperature and recommended ambient temperature in operation. The IC may cross over maximum power dissipation at normal operating condition by power supply voltage or load current within peak current absolute maximum rating value.

*2 . JEDEC STANDARD test board



2) Recommended operating conditions

Recommended values are conditions for guaranteeing that the product operates normally. If it is used out of this condition, there is a possibility of having a negative influence on operation and reliability. Please use it after confirming enough with your products.

Item	Symbol	MIN.	TYP.	MAX.	Unit
High side floating absolute voltage	V_B	V_S+14	V_S+19	V_S+29	V
High side floating supply offset voltage *1	V_S	-5	—	500	V
High side floating supply voltage (V_{BS}=V_B-V_S)	V_{BS}	14	19	29	V
High side floating output voltage	V_{HO}	V_S	—	V_B	V
High side floating pin capacitance *2	C_{VBS}	0.10	0.47	1.00	uF
Low side supply voltage	V_{CC}	14	19	29	V
Low side output voltage	V_{LO}	0	—	V_{CC}	V
Low side supply pin capacitance *3	C_{VCC}	47	100	—	uF
Low side supply pin by-pass capacitance *4	C_{VCC2}	0.10	—	—	uF
VH pin input voltage	V_H	80	—	500	V
VH pin input peak current	I_{VH}	—	—	16	mA
VH pin resistance	R_{VH}	2	10	40	kΩ
VH pin capacitance	C_{VH}	—	—	470	pF
STB pin selection resistance *5	R_{STBA}	32.67	33.0	33.33	kΩ
	R_{STBB}	81.18	82.0	82.82	kΩ
	R_{STBC}	297.0	300.0	303.0	kΩ
STB pin capacitance	C_{STB}	820	1000	1200	pF
FB pin capacitance (Auto standby)	C_{FB_A}	1	22	—	nF
FB pin capacitance (External standby)	C_{FB_B}	0.22	1	—	nF
CA pin capacitance	C_{CA}	0.1	0.47	1.0	uF
CA pin resistance (RSTB=82kΩ)	R_{CAB}	62	OPEN	—	kΩ
CA pin resistance(RSTB=300kΩ)	R_{CAC}	300	OPEN	—	kΩ
VS pin capacitance *6	C_{VS}	100	220	1000	pF
MODE pin selection resistance *5	R_{MODEA}	14.85	15.0	15.15	kΩ
	R_{MODEB}	23.76	24.0	24.24	kΩ
	R_{MODEC}	35.64	36.0	36.36	kΩ
	R_{MODED}	55.44	56.0	56.56	kΩ
	R_{MODEE}	81.18	82.0	82.82	kΩ
	R_{MODEF}	118.8	120.0	121.2	kΩ
	R_{MODEG}	178.2	180.0	181.8	kΩ
	R_{MODEH}	267.3	270.0	272.7	kΩ
	R_{MODEI}	386.1	390.0	393.9	kΩ
MODE pin capacitance	C_{MODE}	1	10	22	nF
CS pin capacitance (Auto standby)	C_{CS_A}	1	4.7	10	nF
CS pin capacitance (External standby)	C_{CS_E}	10	22	47	nF
External resonant inductor *7	L_{RX}	—	0	—	uH
Operating ambient temperature	T_a	-40	—	105	˚C

*1. The voltage of the VB pin must be over 10V.

*2. The high side floating pin capacitance consist a boot-strap circuit, and it should be connected between VS and VB pin. If a surge current is worried in the capacitor charge term, limit the current by the resister

*3. Start-up operation and stand-by mode power consumption are changed by the VCC pin capacitance. Please determine the capacitance with the confirmation of the actual power supply board.

*4. By-pass capacitor must be connected to VCC pin and GND pin near each pin.

*5. Use resistors which tolerance is within 1% at STB pin or MODE pin.

*6. VS pin capacitor achieves stable operation, but it causes a hard switching when the capacitance is too large. Please determine the capacitance with the confirmation of the actual power supply board.

*7. The leakage inductance of the transformer is used as the resonance inductor. The Addition of external resonance inductor is not recommended.

3) DC electrical characteristics

・The characteristics in this section are under the described conditions as follows unless otherwise specified.
The voltages described in conditions are DC input, not AC input.
T_j=25°C, V_H=100V, V_{CC}=19V, V_B=19V, V_S=0V, V_{FB}=2.0V, V_{CS}=3.7V, CA pin open, V_{IS}=0V, V_{VW}=0V, V_{STB} =0V, V_{MODE}=0.55V, LO pin open, HO pin open.
・The columns of '－' have no guaranteed specification.
・The operation described in the table as "switching" means the switching output of HO and LO. The items without description of HO or LO in condition shows the switching operation of both HO and LO.

(1) High voltage input (VH pin, VCC pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
VH pin input current	I_{HRUN1}	V_H=100V, V_{CC}>V_{STOFF}	3.5	5.0	6.5	uA
	I_{HRUN2}	V_H=400V, V_{CC}>V_{STOFF}	16	20	24	uA
	I_{VH0}	V_H=100V, V_{CC}=0V	0.6	1.4	2.5	mA
	I_{VH6}	V_H=100V, V_{CC}=6V	8.4	12.0	15.6	mA
	I_{VH14}	V_H=100V, V_{CC}= V_{CCON}-0.2V	6.3	9.0	11.7	mA
Charge current to VCC pin	I_{PRE0}	V_H=100V, V_{CC}=0V	-2.5	-1.4	-0.6	mA
	I_{PRE6}	V_H=100V, V_{CC}=6V	-14.3	-11.0	-7.7	mA
	I_{PRE14}	V_H=100V, V_{CC}=V_{CCON}-0.2V	-10.4	-8.0	-5.6	mA
Minimum start operation voltage on VH pin	V_{VHMIN}	V_H increasing, VCC open	17	22	27	V
Charging current rate of change to the VH pin	dI_{VH}/dt	V_H=100V, I_{VH}=0.5→2mA	0.3	1.2	3.0	mA/us
Charging current delay time to the VH pin	td_{VH}	V_H=100V, The periode I_{VH} over 2mA after VCCOFF	20	40	60	us

(2) Low-side power supply (VCC pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Start operation voltage	V_{CCON}	V_{CC} increasing, Switching start point, V_{FB}=3.8V	13.2	14.0	14.8	V
Shutdown voltage	V_{CCOFF}	V_{CC} decreasing, Switching stop point	8.5	9.0	9.5	V
IC reset voltage	V_{CCRST}	V_{CC} decreasing, IC reset	8.0	8.5	9.0	V
Start-up circuit start voltage	V_{STON}	V_{CC} decreasing	9.5	10.0	10.5	V
	V_{STON1}	V_{CC} decreasing Start-up or auto recovery	12.8	13.5	14.2	V
Start-up circuit stop voltage	V_{STOFF}	V_{CC} increasing, Normal	10.4	11.0	11.6	V
	V_{STOFF1}	V_{CC} increasing Start-up or auto recovery	13.2	14.0	14.8	V
Hysteresis voltage	V_{CCHYS}	V_{CCHYS}=V_{CCON}-V_{CCOFF}	4.0	5.0	6.0	V
	V_{CCH1}	V_{CCH1}=V_{STOFF}-V_{STON}	0.5	1.0	1.5	V
	V_{CCH2}	V_{CCH2}=V_{STON}-V_{CCOFF}	0.5	1.0	1.5	V
Low-side minimum operating voltage	V_{CCMIN}	LO pin sink current 1mA	1.0	2.8	4.0	V
Startup PFC stop signal output	V_{CCOFF_PFC}	V_{CC} increasing, Start-up	9.5	10.0	10.5	V
Startup PFC resume signal output	V_{CCON_PFC}	V_{CC} increasing, Start-up after mode setting	13.2	14.0	14.8	V
VCC quiescent current at start up	I_{CC0}	V_{CC}=13V, R_{STB}=82kΩ, Start-up	0.2	0.4	0.6	mA
VCC quiescent current	I_{CC1}	V_{CC}=19V, V_{FB}=1.6V, Standby	0.5	0.8	1.0	mA
VCC operating current	I_{CC2}	V_{CC}=19V Switching frequency : 25kHz	0.7	1.1	1.5	mA
	I_{CC3}	V_{CC}=19V Switching frequency : 270kHz	1.2	1.8	2.4	mA

(3) VCC voltage drop protection (VCC pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Drop protection voltage	V_{DVCCL}	V_{CC} decreasing	8.5	9.0	9.5	V
Drop protection disable voltage	V_{DVCCH}	V_{CC} increasing	9.5	10.0	10.5	V
Restart time of drop protection	$t_{DVCCOFF}$	V_{CC} = 19V to V_{DVCCL} -0.2V to 19V,	660	810	960	ms

(4) High-side power supply (VB, VS, HO pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Switching start voltage	V_{BSON}	V_B increasing, V_{FB}=2V, V_S=0V HO switching start point	7.8	8.8	9.8	V
Switching stop voltage	V_{BSOFF}	V_B decreasing, V_{FB}=2V, V_S=0V HO switching stop point	7.0	7.5	8.1	V
Hysteresis voltage	V_{BSHYS}	V_{BSHYS}=V_{BSON}-V_{BSOFF}	0.5	1.3	2.0	V
High-side minimum operating voltage	V_{BSMIN}	HO pin sink current 1mA	0.6	2.2	3.0	V
High-side quiescent current	I_{BS1}	V_{FB}=0V, HO switching stops	20	30	50	uA
High-side operating current	I_{BS2}	V_{BS}=19V Switching frequency : 25kHz	50	80	110	uA
	I_{BS3}	V_{BS}=19V Switching frequency : 270kHz	0.35	0.50	0.65	mA

(5) MODE Selection (MODE pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Mode selection source current	I_{MODE1}	V_{MODE}=0V	-43.2	-40.0	-36.8	uA
	I_{MODE2}	V_{MODE}=0V	-10.8	-10.0	-9.2	uA
	I_{MODE3}	V_{MODE}=0V	-3.3	-3.0	-2.7	uA
Mode selection time	t_{MODE1}	C_{MODE}=2.2nF, R_{MODE}=56kΩ	12	15	18	ms
	t_{MODE2}	C_{MODE}=10nF,R_{MODE}=180kΩ	24	30	36	ms
	t_{MODE3}	C_{MODE}=10nF,R_{MODE}=390kΩ	32	40	48	ms
Mode selection source current switch voltage	V_{MODE12}	$I_{MODE1} \rightarrow I_{MODE2}$	2.46	2.65	2.84	V
	V_{MODE23}	$I_{MODE2} \rightarrow I_{MODE3}$	2.93	3.15	3.37	V
Mode selection resistor open detection voltage	V_{MODEO}	No Switching if $V_{MODE} > V_{MODEO}$	1.33	1.40	1.47	V
VCC charge resume voltage	V_{MODER}	Decreasing V_{MODE}	0.60	0.65	0.70	V
Discharge time at initial reset	t_{MRES}		0.5	0.8	1.1	ms
Discharge resistance at initial reset	R_{MRES}		1.2	2.4	3.6	kΩ

Mode selection at MODE pin

MODE	MODE pin resistance	CA pin voltage when the standby operation is switched to the normal operation		VW pin threshold voltage of forced turn-off	
		LLC	PFC	Low side	High side
A	15kΩ	300mV	300mV	-1.2V	1.4V
B	24kΩ	300mV	300mV	-1.0V	1.2V
C	36kΩ	300mV	300mV	-0.8V	1.0V
D	56kΩ	400mV	400mV	-1.2V	1.4V
E	82kΩ	400mV	400mV	-1.0V	1.2V
F	120kΩ	400mV	400mV	-0.8V	1.0V
G	180kΩ	600mV	600mV	-1.2V	1.4V
H	270kΩ	600mV	600mV	-1.0V	1.2V
I	390kΩ	600mV	600mV	-0.8V	1.0V

(6) External-fault stop function (MODE pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
MODE pin source current	I_{MODESC}	V_{MODE}=0V	-150	-110	-70	uA
Threshold voltage for external-fault stop	V_{MODEST}	V_{MODE} decreasing, Switching stop point	0.30	0.35	0.40	V
Clamp voltage	$V_{MODECLP}$	I_{MODE}=-10uA	0.48	0.53	0.58	V
Delay time to external-fault stop	$t_{MODEDLY}$		244	304	364	us
Restart time of external-fault stop	$t_{MODEOFF}$		660	810	960	ms

(7) Input voltage detection (VH pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage mode switching voltage	V_{INH}	V_H increasing, High V_H mode	207	230	253	V
			(146)	(163)	(179)	(Vac)
	V_{INL}	V_H decreasing, Low V_H mode	189	210	231	V
			(134)	(148)	(163)	(Vac)
Set switching delay time to the high input voltage mode	$t_{DLY1to2}$	V_H increasing, Low V_H mode to High V_H mode	112	160	208	us
Set switching delay time to the low input voltage mode	$t_{DLY2to1}$	V_H increasing, High V_H mode to Low V_H mode	21.0	26.5	32.0	ms

(8) X-CAP Discharge Function (VH pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
VH Amplitude ensured AC detection (Note1)	V_{HACDET}	V_H=20V to 100V	50	–	–	V
		V_H=200V to 350V	75	–	–	V
Delay time of AC cutting Detection	t_{ACDET}		42	56	70	ms
Average discharge current of X-CAP	I_{XCD}	V_H=120V	1	2	4	mA
On Discharge time	t_{ONXCD}		1.2	1.5	1.8	ms
Off discharge time	t_{OFFXCD}		0.4	0.5	0.6	ms

(Note 1) Input the signal of the amplitude more than the rated value.

(9) Oscillator (FB pin, CS pin, HO pin, LO pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Duty cycle	D_{UTY}	V_{CC}=19V, V_B=19V, V_{FB}=2V, (Note 2)	48	50	52	%
Maximum oscillation frequency	f_{MAX}	V_{CC}=19V, V_B=19V, Initial of soft start	370	450	530	kHz
	f_{MAX_N}	V_{CC}=19V, V_B=19V, V_{FB}=0.8V	240	300	360	kHz
	f_{MAX_FB}	V_{CC}=19V, V_B=19V, V_{FB}=0.9V	220	270	320	kHz
Minimum oscillation frequency	f_{MIN}	V_{CC}=19V, V_B=19V, V_{FB}=3.0V	20	25	30	kHz

(Note 2) The duty of high side and low side are common because of HO and LO are symmetric at phase difference 180 degrees. If the times are defined as follows, the duty D_{UTY} is shown as following equation.

$D_{UTY} = (t_{H1}-t_{L1}) / (t_{L2}-t_{L1}) = (t_{L2}-t_{H1}) / (t_{H2}-t_{H1})$

t_{L1}:A certain LO turn-on point

t_{H1}:A HO turn-on point just after LO turn-off after t_{L1}

t_{L2}:A LO turn-on point just after HO turn-off after t_{H1}

t_{H2}:A HO turn-on point just after LO turn-off after t_{L2}

(10) Self-adjusting dead time function (VW pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Min. $\|dV_{VW}/dt\|$ of low side turn on (Note3)	$-DV_{VWM}$	(Note 4)	0.6	-	-	V/us
Min. $\|dV_{VW}/dt\|$ of high side turn on (Note3)	DV_{VWP}	(Note 5)	0.6	-	-	V/us
Delay time for VW pin detection in low side turn on	t_{DVWONM}	V_{STB}=1V	150	300	450	ns
Delay time for VW pin detection in high side turn on	t_{DVWONP}	V_{STB}=1V	150	300	450	ns
Minimum dead time	t_D		380	430	480	ns
Maximum dead time	t_{DMAX}		22	25	28	us

(Note 3) Input the signal of the inclination more than the rated value.
(Note 4) After V_{VW} raise to 4V from 0V, fall with the slope of DV_{VWM} ($=-dV_{VW}/dt$) toward -4V, and detect the LO turn-on point.
(Note 5) After VVW fall to -4V from 0V, raise with the slope of DV_{VWP}($=dV_{VW}/dt$) toward 4V, and detect the HO turn-on point.

(11) Feedback section (FB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
FB pin source current	I_{FB}	V_{FB}=0V	-250	-190	-130	uA
FB pin input resistance	R_{FB}	$I_{FB\_1V}=I_{FB}$ at V_{FB}=1V, $I_{FB\_2V}=I_{FB}$ at V_{FB}=2V, $R_{FB}=1V/(I_{FB\_1V}-I_{FB\_2V})$	18	26	34	kΩ
Switching start voltage	V_{FBON}	V_{FB} increasing	0.60	0.70	0.90	V
Switching stop voltage	V_{FBOFF}	V_{FB} decreasing	0.50	0.60	0.70	V
Hysteresis voltage	V_{FBHYS}	$V_{FBHYS}=V_{FBON}-V_{FBOFF}$	0.05	0.10	0.15	V
FB pin discharge resistance	R_{FBDCHG}	$I_{FB\_1V}=I_{FB}$ at V_{FB}=1V, $I_{FB\_2V}=I_{FB}$ at V_{FB}=2V, $R_{FB}=1V/(I_{FB\_1V}-I_{FB\_2V})$	10.0	12.5	15.0	kΩ

(12) External standby operation (FB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
FB pin burst soft-start start voltage	V_{FBSS}	FB increasing, CS pin open V_{STB}=1V, R_{STB}=33kΩ	3.9	4.1	4.3	V
FB pin burst soft-end start voltage	V_{FBSE}	FB decreasing, CS pin open V_{STB}=1V, R_{STB}=33kΩ	3.7	3.9	4.1	V
Hysteresis voltage	V_{FBSHYS}	$V_{FBSHYS}=V_{FBSS}-V_{FBSE}$	0.15	0.2	0.25	V

(13) Auto standby operation (FB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
FB pin burst soft-start start voltage	V_{FBSS1_AUT1}	Charge period after Normal → Standby, V_{CS}=1V, V_{FB} increasing	3.9	4.1	4.3	V
	V_{FBSS2_AUT2}	Charge period after Normal → Standby, V_{CS}=0.2V, V_{FB} increasing	1.8	1.9	2.0	V
FB pin burst soft-end start voltage	V_{FBSE1_AUT1}	Discharge period after Normal → Standby, V_{CS}=1V, V_{FB} decreasing	3.7	3.9	4.1	V
	V_{FBSE2_AUT2}	Discharge period after Normal → Standby, V_{CS}=0.2V, V_{FB} decreasing	1.5	1.6	1.7	V
Hysteresis voltage	$V_{FBSHYS1\_AUT}$	$V_{FBSHYS1}=V_{FBSS\_AUT1}-V_{FBSE\_AUT1}$	0.15	0.2	0.25	V
	$V_{FBSHYS2\_AUT}$	$V_{FBSHYS2}=V_{FBSS\_AUT2}-V_{FBSE\_AUT2}$	0.2	0.3	0.4	V
FB pin burst removal voltage	V_{FBBS_AUT}	V_{FB} increasing	2.35	2.50	2.65	V

(14) Soft start operation (CS pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Charging current (VB low input, External standby)	I_{CSSO1}	Start-up, V_{CS}=0V, V_B=100V, R_{STB}=33kΩ	-4.8	-4.0	-3.2	uA
Charging current (VB high input, External standby)	I_{CSSO2}	Start-up, V_{CS}=0V, V_B=420V, R_{STB}=33kΩ	-2.2	-2.0	-1.8	uA
Charging current (Auto standby	I_{CSSO_AUT}	Start-up, V_{CS}=0V, R_{STB}=82kΩ or 300kΩ	-2.2	-2.0	-1.8	uA
CS pin operation start voltage	V_{CSONS}	Start-up, Vcs increasing	0.35	0.40	0.45	V
CS pin operation stop voltage	V_{CSOFFS}	Start-up, Vcs decreasing	0.30	0.35	0.40	V
Hysteresis voltage	V_{CSHYSS}	$V_{CSHYSS}=V_{CSONS}-V_{CSOFFS}$	0.02	0.05	0.10	V
Soft-start removal voltage	V_{CSSF}	V_{CS} increasing	2.60	2.80	3.00	V

(15) External standby operation (CS pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CS pin charge current	I_{CSCHG1}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS}=3V, V_H=100V, R_{STB}=33kΩ	-48	-40	-32	uA
	I_{CSCHG2}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS}=3V, V_H=300V, R_{STB}=33kΩ	-24	-20	-16	uA
CS pin discharge current	I_{CSDIS1}	Standby, V_{STB}=1V, V_{FB}=3.5V, V_{CS}=0V, V_H=100V, R_{STB}=33kΩ	64	80	96	uA
	I_{CSDIS2}	Standby, V_{STB}=1V, V_{FB}=3.5V, V_{CS}=0V, V_H=300V, R_{STB}=33kΩ	32	40	48	uA
CS pin operation start voltage	V_{CSON1}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS} increasing, V_B=100V, R_{STB}=33kΩ	1.00	1.10	1.20	V
	V_{CSON2}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS} increasing, V_B=420V, R_{STB}=33kΩ	1.55	1.70	1.85	V
CS pin operation stop voltage	V_{CSOFF1}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS} decreasing, V_B=100V, R_{STB}=33kΩ	0.90	1.00	1.10	V
	V_{CSOFF2}	Standby, V_{STB}=1V, V_{FB}=4.5V, V_{CS} decreasing, V_B=420V, R_{STB}=33kΩ	1.45	1.60	1.75	V
CS pin hysteresis voltage	V_{CSHYS1}	$V_{CSHYS1}=V_{CSON1}-V_{CSOFF1}$	0.05	0.10	0.15	V
	V_{CSHYS2}	$V_{CSHYS2}=V_{CSON2}-V_{CSOFF2}$	0.05	0.10	0.15	V

(16) Auto standby operation (CS pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CS pin charge current 1	I_{CSCHG_AUT1}	Standby, V_{FB}=2.2V, V_{CS}=0V, R_{STB}=82kΩ,R_{MODE}=390kΩ Vca=300mV	-48	-40	-32	uA
CS pin discharge current 1	I_{CSDIS_AUT1}	Standby, V_{FB}=1.5V, V_{CS}=1V, R_{STB}=82kΩ,R_{MODE}=390kΩ Vca=300mV	64	80	96	uA
CS pin charge current 2	I_{CSCHG_AUT2}	Standby, V_{FB}=2.2V, V_{CS}=0V, R_{STB}=82kΩ,R_{MODE}=390kΩ Vca=600mV	-24	-20	-16	uA
CS pin discharge current 2	I_{CSDIS_AUT2}	Standby, V_{FB}=1.5V, V_{CS}=1V, R_{STB}=82kΩ,R_{MODE}=390kΩ Vca=600mV	32	40	48	uA
CS pin switching start voltage	V_{CSON_AUT}	Standby, V_{CS} increasing, Switching start, R_{STB}=82kΩ or 300kΩ	0.31	0.37	0.42	V
CS pin switching stop voltage	V_{CSOFF_AUT}	Standby, V_{CS} decreasing, Switching stop, R_{STB}=82kΩ or 300kΩ	0.28	0.34	0.40	V
CS pin hysteresis voltage	V_{CSHYS_AUT}	$V_{CSHYS\_AUT}=V_{CSON\_AUT}-V_{CSOFF\_AUT}$	0.01	0.03	0.05	V
CS pin clamp voltage	V_{CSCLP_AUT}	Standby, V_{FB}=2.2V, CS pin open, R_{STB}=82kΩ or 300kΩ	0.9	1.0	1.1	V
	V_{CSCLP1_AUT}	Standby, V_{FB}=2.2V, I_{CS}=-20uA, R_{STB}=82kΩ or 300kΩ	0.9	1.0	1.1	V
CS pin clamp removal delay	t_{CSCLP_AUT}	Standby → Normal , V_{FB}=2.2V, R_{STB}=82kΩ or 300kΩ,	486	608	730	us

(17) Mode selection (STB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
State setting period source current	I_{STBM}	V_{STB}=0V, Mode setting periode	-42	-36	-30	uA
State setting (Judge standby detection)	$V_{STBDET1}$	Auto / external standby State set threshold voltage	1.7	1.9	2.1	V
	$V_{STBDET2}$	OLP at the CA pin State set threshold voltage	3.5	3.8	4.1	V

Mode selection at STB pin

Mode	STB pin resistance	Standby detection method	OLP voltage at the CA pin	
			Symbol	Voltage
A	33kΩ	External standby	$V_{CAOLPH1}$	1.5V
B	82kΩ	Auto standby1	$V_{CAOLPH1}$	1.5V
C	300kΩ	Auto standby2	$V_{CAOLPH2}$	3.0V

(18) External standby operation low standby mode input and output (STB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Source current at the input pin.	I_{STBIN}	V_{STB} =0V, R_{STB}=33kΩ,	-42	-36	-30	uA
Low standby mode detection voltage.	V_{THSTBH}	V_{STB} increasing, R_{STB}=33kΩ,	0.30	0.35	0.40	V
	V_{THSTBL}	V_{STB} decreasing, R_{STB}=33kΩ,	0.25	0.30	0.35	V

(19) Auto standby operation PFC communication function (STB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
PFC stop signal output voltage	V_{STB_STP}	PFC Stop, R_{STB}=82kΩ or 300kΩ	4.0	4.6	5.3	V
PFC stop signal source current.	I_{STB_STP}	PFC Stop, V_{STB}=0V、R_{STB}=82kΩ or 300kΩ	-130	-100	-70	uA
PFC mode switching output signal voltage	V_{STB_MOD}	PFC Normal → PFC Standby , R_{STB}=82kΩ or 300kΩ	2.5	2.9	3.3	V
PFC mode switching signal source current	I_{STB_MOD}	PFC Normal → PFC Standby, V_{STB}=0V、R_{STB}=82kΩ or 300kΩ	-80	-60	-40	uA
PFC standby signal output time.	t_{P_STB}	PFC Normal → PFC Standby, R_{STB}=82kΩ or 300kΩ	5.2	6.0	7.2	ms
PFC normal signal output time.	t_{P_NOM}	PFC Standby → PFC Normal, R_{STB}=82kΩ or 300kΩ	0.35	0.5	0.65	ms
Input voltage switching signal output voltage.	V_{STB_VIN}	PFC Standby, V_H=300V → 100V, R_{STB}=82kΩ or 300kΩ	2.5	2.9	3.3	V
Input voltage switching signal source current.	I_{STB_VIN}	PFC Standby, V_{STB}=0V、 R_{STB}=82kΩ or 300kΩ	-80	-60	-40	uA
The number of times of the output pulse at the time of the high input voltage.	$N_{P\_VIN\_H}$	PFC Normal, V_H=300V, R_{STB}=82kΩ or 300kΩ	-	1	-	time
The number of times of the output pulse at the time of the low input voltage.	$N_{P\_VIN\_L}$	PFC Normal, V_H=100V, R_{STB}=82kΩ or 300kΩ	-	2	-	times
Blanking signal output voltage.	V_{STB_BLK}	PFC Normal, R_{STB}=82kΩ or 300kΩ	-0.1	0	0.1	V
Startup PFC output stop time.	$t_{P\_STOP\_PFC}$	PFC switching period after Mode selection at startup, R_{STB}=82kΩ or 300kΩ	240	320	400	ms

(20) Input current detection (CA pin, IS pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CA pin voltage	V_{CA400_1}	V_{IS}=0.4V, V_B=420V, V_{vw}=Pulse (Note6)	0.95	1.00	1.05	V
	V_{CA400_2}	V_{IS}=0.2V, V_B=420V, V_{vw}=Pulse (Note6)	0.92	1.00	1.08	V
	V_{CA400_3}	V_{IS}=0.1V, V_B=420V, Vvw=Pulse, (Note 6)	0.89	1.00	1.11	V
	V_{CA400_4}	V_{IS}=0.04V, V_B=420V, Vvw=Pulse, (Note 6)	0.32	0.40	0.48	V
	V_{CA_R}	V_{IS}=1V, V_B=420V, V_{vw}=Pulse ,R_{CA}=62kΩ(Note6)	0.80	0.95	1.10	V
CA pin internal resistance	R_{CAO}	$R_{CAO}=(V_{CA0}-V_{CA15})$/15uA V_{CA0}: CA pin voltage of I_{CA}=0uA, V_{CA15}: CA pin voltage of I_{CA}=-15uA	95	100	105	kΩ

(Note6) VW pin is input by square wave (pulse).
The definition of the pulse: Frequency 100kHz, Duty 50%, High level 1V, Low level -1V.

(21) Input current detection gain switching (CA pin, IS pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CA pin gain	G_{CAIS1}	V_{IS}=0.4V, Vvw=Pulse $\Delta V_{CA}/\Delta V_{IS}$	2.4	2.5	2.6	V/V
	G_{CAIS2}	V_{IS}=0.08V, Vvw=Pulse $\Delta V_{CA}/\Delta V_{IS}$	4.8	5.0	5.2	V/V
	G_{CAIS4}	V_{IS}=0.04V, Vvw=Pulse , g4=V_{CA}/V_{IS}, $\Delta V_{CA}/\Delta V_{IS}$	9.5	10.0	10.5	V/V
Gain down at the time of the trigger voltage of CA pin	$V_{CAGDOWN}$	V_{CA} increasing	1.30	1.45	1.60	V
Gain up at the time of the trigger voltage of CA pin	V_{CAGUP}	V_{CA} decreaing	0.50	0.60	0.70	V
Gain switching delay time	t_{DLYGCA}	V_{IS}=400mV → 250mV	0	64	160	us

(22) Over load protection (CA pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Over load protection operation voltage1	$V_{CAOLPH1}$	V_{CA} increasing, R_{STB}=33kΩ or 82kΩ	1.38	1.50	1.62	V
Over load protection removal voltage1	$V_{CAOLPL1}$	V_{CA} decreasing, R_{STB}=33kΩ or 82kΩ	1.29	1.40	1.51	V
Hysteresis voltage1	$V_{CAOHYS1}$	$V_{CAOHYS1}=V_{CAOLPH1}-V_{CAOLPL1}$, R_{STB}=33kΩ or 82kΩ	0.05	0.10	0.15	V
Over load protection operation voltage2	$V_{CAOLPH2}$	V_{CA} decreasing, R_{STB}=300kΩ	2.75	3.00	3.25	V
Over load protection removal voltage2	$V_{CAOLPL2}$	V_{CA} increasing, R_{STB}=300kΩ	2.55	2.80	3.05	V
Hysteresis voltage2	$V_{CAOHYS2}$	$V_{CAOHYS2}=V_{CAOLPH2}-V_{CAOLPL2}$, R_{STB}=300kΩ	0.10	0.20	0.30	V
Over load protection delay time	t_{D_CAOLP}	Switching stop, V_{CA}=0V to 4V	30.0	38.0	46.0	ms
Restart time of over current and over load	$t_{OFFCAOLP}$	The term of switching stop	660	810	960	ms

(23) Auto standby operation (CA pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LLC standby detection voltage1	$V_{CASTBL1}$	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=A,B,C	270	300	330	mV
LLC normal return voltage1	$V_{CASTBH1}$	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=A,B,C	320	350	380	mV
Hysteresis voltage1	$V_{CASTBY1}$	$V_{CASTBY1}=V_{CASTBH1}-V_{CASTBL1}$ R_{STB}=82kΩ or 300kΩ, MODE=A,B,C	20	50	80	mV
LLC standby detection voltage2	$V_{CASTBL2}$	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=D,E,F	370	400	430	mV
LLC normal return voltage2	$V_{CASTBH2}$	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=D,E,F	420	450	480	mV
Hysteresis voltage2	$V_{CASTBY2}$	$V_{CASTBY2}=V_{CASTBH2}-V_{CASTBL2}$ R_{STB}=82kΩ or 300kΩ, MODE=D, E, F	20	50	80	mV
LLC standby detection voltage3	$V_{CASTBH3}$	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=G,H,I	550	600	650	mV
LLC normal return voltage3	$V_{CASTBH3}$	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=G,H,I	650	700	750	mV
Hysteresis voltage3	$V_{CASTBY3}$	$V_{CASTBY3}=V_{CASTBH3}-V_{CASTBL3}$ R_{STB}=82kΩ or 300kΩ, MODE=G, H, I	40	100	160	mV
LLC auto standby operation delay time	$t_{D\_CAS\_LLC}$	V_{CA}=1.3V to 0V, R_{STB}=82kΩ or 300kΩ	88	108	128	ms
CS pin voltage1 of switch the CS pin current	V_{CASSL1}	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=A,B,C	170	200	230	mV
	V_{CASSH1}	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=A,B,C	220	250	280	mV
Hysteresis of CS pin voltage 1	V_{CASSY1}	$V_{CASSY1}=V_{CASSH1}-V_{CASSL1}$	20	50	80	mV
CS pin voltage2 of switch the CS pin current	V_{CASSL2}	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=D,E,F	270	300	330	mV
	V_{CASSH2}	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=D,E,F	320	350	380	mV
Hysteresis of CS pin voltage 2	V_{CASSY2}	$V_{CASSY2}=V_{CASSH2}-V_{CASSL2}$	20	50	80	mV
CS pin voltage 3 of switch the CS pin current	V_{CASSL3}	V_{CA} decreasing, R_{STB}=82kΩ or 300kΩ, MODE=G,H,I	350	400	450	mV
	V_{CASSH3}	V_{CA} increasing, R_{STB}=82kΩ or 300kΩ, MODE=G,H,I	450	500	550	mV
Hysteresis of CS pin voltage 3	V_{CASSY3}	$V_{CASSY3}=V_{CASSH3}-V_{CASSL3}$	40	100	160	mV

(24) Low-side gate driver (LO pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
High level output voltage	V_{OH_LO}	I_{OL}=-100mA	15.0	17.0	18.5	V
Low level output voltage	V_{OL_LO}	V_{CC}=19V, V_{FB}=0V, I_{OL}=+100mA	0.3	0.6	0.9	V
High level shorted current	I_{OH_LO}	(Note 7)	-0.8	-0.5	-0.3	A
Low level shorted current	I_{OL_LO}	(Note 8)	0.5	1.0	1.5	A
Rise time	t_{R_LO}	C_{LO}=1000pF, LO level 10% to 90%	10	50	100	ns
Fall time	t_{F_LO}	C_{LO}=1000pF, LO level 90% to 10%	5	35	70	ns

(Note 7) Pulse input to LO, negative pulse width<1us, 1pulse, low level VLO=0V.
(Note 8) Pulse input to LO, positive pulse width<1us, 1pulse, high level VLO=19V.

(25) High-side gate driver (HO pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
High level output voltage	V_{OH_HO}	V_{BS}=19V, V_S=0V, V_{FB}=2V, I_{OH}=-100mA	14.0	16.0	18.5	V
Low level output voltage	V_{OL_HO}	V_{BS}=19V, V_S=0V, V_{FB}=2V, I_{OH}=+100mA	0.2	0.5	0.8	V
High level shorted current	I_{OH_HO}	V_{BS}=19V, V_S=0V, (Note 9)	-0.8	-0.5	-0.3	A
Low level shorted current	I_{OL_HO}	V_{BS}=19V, V_S=0V, (Note 10)	0.6	1.2	1.8	A
Rise time	t_{R_HO}	V_{BS}=19V, V_S=0V, C_{HO}=1000pF HO level 10% to 90%	10	50	100	ns
Fall time	t_{F_HO}	V_{BS}=19V, V_S=0V, C_{HO}=1000pF HO level 90% to 10%	5	30	60	ns

(Note 9) Pulse input to HO, negative pulse width<1us, 1pulse, low level V_{HO}=0V.
(Note 10) Pulse input to HO, positive pulse width<1us, 1pulse, high level V_{HO}=19V.

(26) Brown out protection (VH pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Brown-in voltage	V_{BI1}	V_H increasing Switching started point	85.0 (60.0)	92.0 (65.1)	97.0 (68.6)	V (V_{ac})
Brown-out voltage	V_{BO1A}	V_H decreasing Switching stopped point	56.0 (39.6)	61.0 (43.1)	66.0 (46.7)	V (V_{ac})
Hysteresis voltage	V_{BOHYS1}	$V_{BOHYS1} = V_{BI1} – V_{BO1A}$	25.0	31.0	37.0	V
Delay time for Brown-in	t_{PDBI}		112	160	208	us
Delay time for Brown-out	t_{PDBO1}	(Note 11)	38.0	47.0	56.0	ms

(Note 11) VH decreasing, VFB=2V, the term from VH step input as VH<VBO to switching stopped point.

(27) Brown out protection (VB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{BBO}	V_B decreasing, V_H=0V	47.2	52.5	57.5	V
Detection cancellation voltage	V_{BBI}	V_B increasing, V_H=0V	54	60	66	V
Hysteresis voltage	V_{BHYS}	V_{BHYS}=V_{BBI}-V_{BBO}	6.0	7.5	9.0	V
Delay time	t_{DLVBBO}	Switching stop after V_B=100V to 0V, V_H=0V	486	608	730	us

(28) Over voltage protection (VCC pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Over voltage threshold	V_{CCOVP1}	V_{CC} increasing, V_{FB}=2V, Switching stopped point	29.2	30.6	32.0	V
Delay time to over voltage	t_{VCCDLY}	(Note 12)	244	304	364	us
Over voltage protection stop time	t_{VCCOFF}		660	810	960	ms

(Note 12) V_{CC} increasing, V_{FB}=2V, the term from V_{CC} step input as V_{CC}>V_{CCOVP1} to switching stopped point.

(29) Over current protection (IS pin, MODE pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Over current detection voltage of low side	V_{OCMN}	Normal mode, V_{IS} decreasing	-4.25	-4.0	-3.75	V
	V_{OCMS}	Standby or OLP of FB pin	-2.75	-2.60	-2.45	V
Over current detection voltage of high side	V_{OCPN}	Normal mode, V_{IS} increasing	3.75	4.0	4.25	V
	V_{OCPS}	Standby or OLP of FB pin	2.45	2.60	2.75	V
Delay time for low side turn off in over current	t_{DLOCM}	V_{FB}=2V, (Note 13)	100	160	260	ns
Delay time for high side turn off in over current	t_{DLOCP}	V_{FB}=2V, (Note 14)	100	160	260	ns
Reset time of over current detection	t_{OCRST}	V_{FB}=2V, (Note 15)	60	76	92	us
Delay time of over current (MODE pin)	$V_{OCPDLYL}$	Start voltage for charge	0.60	0.65	0.70	V
	$V_{OCPDLYH}$	Start voltage for discharge	1.25	1.40	1.55	V
	$V_{OCPDHYS}$	$V_{OCPDHYS}$ = $V_{OCPDLYH}$ -$V_{OCPDLYL}$	0.50	0.75	1.00	V
	$I_{OCPDLYC}$	Charge current	-80	-65	-50	uA
	$I_{OCPDLYD}$	Discharge current	50	65	80	uA
	N_{OCPDLY}	Cycle number of charge and discharge	-	32	-	cycle
Restart time of OCP	t_{OCOFF}	The term of switching stop	660	810	960	ms
IS level shift resistance	R_{ISLVS}	V_{IS}=0V	400	480	560	kΩ

(Note 13) The term from VIS step input (-3V to -5V) to LO turn-off point.
(Note 14) The term from VIS step input (+3V to +5V) to HO turn-off point.
(Note 15) VIS is step pulse inputted (0V to -4.5V). The pulse period where the OCP operates by decreasing the pulse period.

(30) Over load Protection (FB pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Over load detection voltage	V_{OLPFBH}	V_{FB} increasing Switching stop point	4.1	4.3	4.5	V
Over load detection disable voltage	V_{OLPFBL}	V_{FB} decreasing, Return point of repeated restart	3.9	4.1	4.3	V
Hysteresis voltage	$V_{OLPFBHYS}$	$V_{OLPFBHYS}$ =V_{OLPFBH} - V_{OLPFBL}	0.1	0.2	0.3	V
Delay time of over current and over load	t_{OLPDLY}	V_{FB}=4.5V, The term of switching	60.8	76.8	92.8	ms
Restart time of over current and over load	t_{OLPOFF}	V_{FB}=2V, The term of switching stop	660	810	960	ms

(31) Preventing Arm-short function (IS pin, VW pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Blanking time for forced turn off	t_{VWDET}	V_{IS}=0V, V_{VW} pulse step input V_{VW}=0V to -1.5V, VW detection ignored time	300	500	700	ns
VW pin threshold voltage of low side forced turn-off						
Normal mode	V_{THVWPN}	Normal mode	0.35	0.40	0.45	V
External standby, Standby mode	$V_{THVWPS4}$	External standby, V_B=400V, R_{STB}=33kΩ	-0.90	-0.80	-0.70	V
	$V_{THVWPS1}$	External standby, V_B=100V, R_{STB}=33kΩ	-0.15	0.2	0.25	V
Auto standby, Standby mode	V_{THVWPS_AUT1}	Auto standby, Standby mode, R_{STB}=82kΩ or 300kΩ	-1.5	-1.4	-1.3	V
	V_{THVWPS_AUT2}	Auto standby, Standby mode, R_{STB}=82kΩ or 300kΩ	-0.9	-0.8	-0.7	V
Auto standby, Vcs clamp periode after Standby → Normal,	$V_{THVWPSM1\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=A,D,G	-1.3	-1.2	-1.1	V
	$V_{THVWPSM2\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=B,E,H	-1.1	-1.0	-0.9	V
	$V_{THVWPSM3\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=C,F,I	-0.9	-0.8	-0.7	V
VW pin threshold voltage of high side forced turn-off						
Normal mode	V_{THVWMN}	Normal mode	-0.25	-0.20	-0.15	V
External standby, Standby mode	$V_{THVWMS4}$	External standby, V_B=400V, R_{STB}=33kΩ	0.90	1.00	1.10	V
	$V_{THVWMS1}$	External standby, V_B=100V, R_{STB}=33kΩ	-0.05	0	0.05	V
Auto standby, Standby mode	V_{THVWMS_AUT1}	Auto standby, Standby mode, R_{STB}=82kΩ or 300kΩ	1.5	1.6	1.7	V
	V_{THVWMS_AUT2}	Auto standby, Standby mode, R_{STB}=82kΩ or 300kΩ	0.9	1.0	1.1	V
Auto standby, Vcs clamp periode after Standby → Normal,	$V_{THVWMSM1\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=A,D,G	1.3	1.4	1.5	V
	$V_{THVWMSM2\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=B,E,H	1.1	1.2	1.3	V
	$V_{THVWMSM3\_AUT}$	Auto standby, Vcs clamp periode after Standby → Normal, R_{STB}=82kΩ or 300kΩ, MODE=C,F,I	0.9	1.0	1.1	V

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
VW pin detection delay time of low side forced turn-off	$t_{DVWOFFP}$	The term from V_{VW} pulse step input V_{VW}=0V to +2V to LO turn-off	50	100	200	ns
VW pin detection delay time of high side forced turn-off	$t_{DVWOFFM}$	The term from V_{VW} pulse step input V_{VW}=0V to -2V to HO turn-off	50	100	200	ns
IS pin threshold voltage of low side forced turn-off	V_{THISM}	(Note 16)	-1.25	-1.10	-0.95	V
IS pin threshold voltage of high side forced turn-off	V_{THISP}	(Note 17)	0.95	1.10	1.25	V
IS pin detection delay time of low side forced turn-off	$t_{DISOFFM}$	The term from V_{VW} pulse step input V_{VW}=0V to +1.5V, and V_{IS}=-2V to -0.5V to LO turn-off	50	100	200	ns
IS pin detection delay time of high side forced turn-off	$t_{DISOFFP}$	The term from V_{VW} pulse step input V_{VW}=0V to -1.5V, and V_{IS}= 2V to 0.5V to HO turn-off	50	100	200	ns

(Note 16) 2us after LO turn-off, step signal (0V to +1.5V) inputted to VVW. Successively, pulse step signal is inputted to IS pin as width 2us and amplitude 0V to $-V_{IS}$ with increasing the V_{IS}. Detect LO turn-off level.
(Note 17) 2us after HO turn-off, step signal (0V to -1.5V) inputted to VVW. Successively, pulse step signal is inputted to IS pin as width 2us and amplitude 0V to $+V_{IS}$ with increasing the V_{IS}. Detect HO turn-off level.

(32) Unbalance detection (VW pin)

Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Difference of maximum ON Period	D_{ON_MAX}	$D_{ON\_MAX}=T_{ON\_2}-T_{ON\_1}$ T_{on_1} is the previous cycle of T_{ON_2}	0.5	2.0	3.5	us

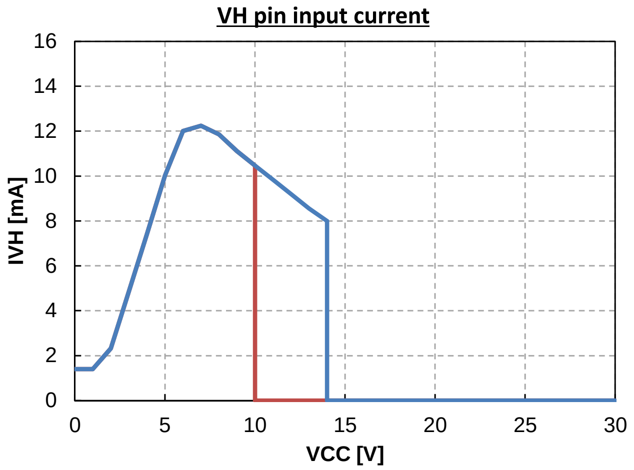
(33) Thermal shutdown protection (Without external pin)

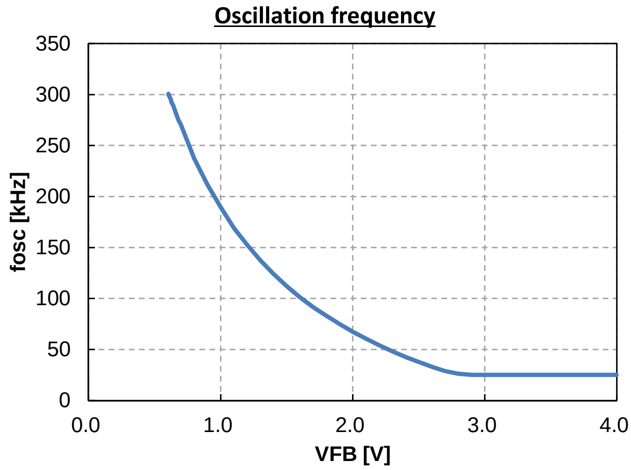
Item	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Thermal shutdown temperature	T_{JOH}	V_{CC}=19V, V_{FB}=2V, Switching stopped point	130	140	150	˚C
Restart temperature	T_{JOHR}	V_{CC}=19V, V_{FB}=2V, Switching restart point	110	120	130	˚C

7. DC typical characteristics

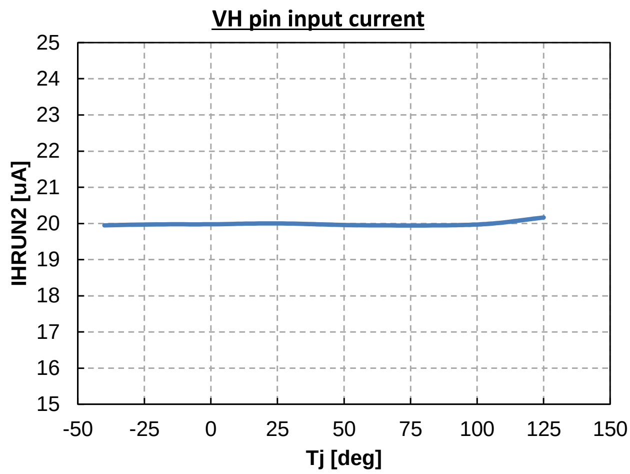
- The conditions are as follows unless otherwise specified.
  T_j=25˚C, V_H=100V, V_{CC}=19V, V_B=19V, V_S=0V, V_{FB}=2.0V, V_{CS}=3.7V, CA pin open, V_{IS}=0V, V_{VW}=0V, V_{STB} =0V, V_{MODE}=0.55V, LO pin open, HO pin open.
- The data listed here show the typical characteristics of an IC, and it does not guarantee the characteristic.

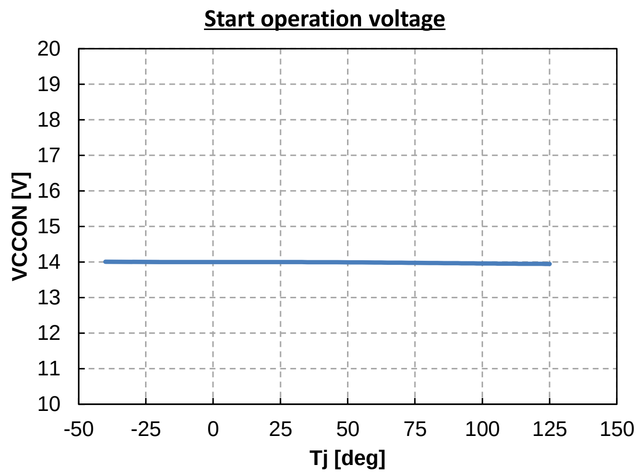
Voltage dependence

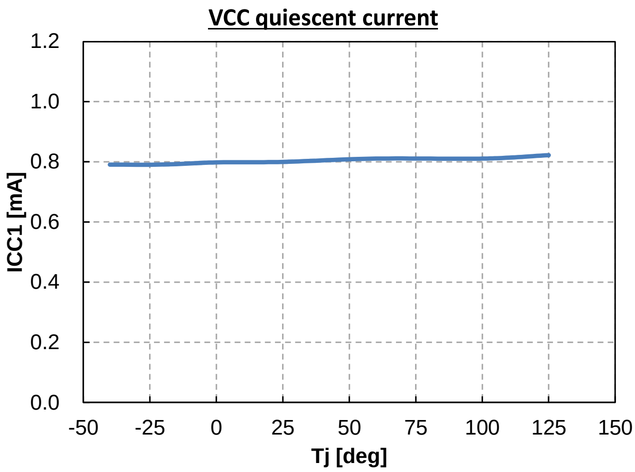


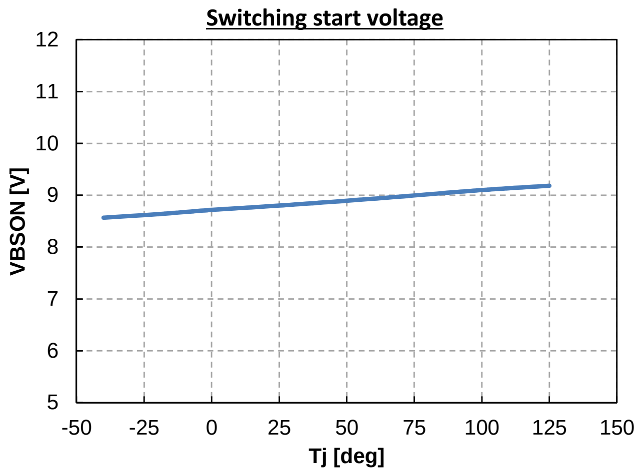


Temperature characteristics

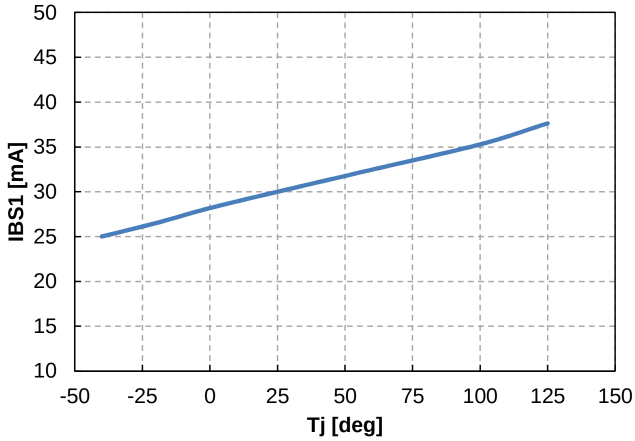




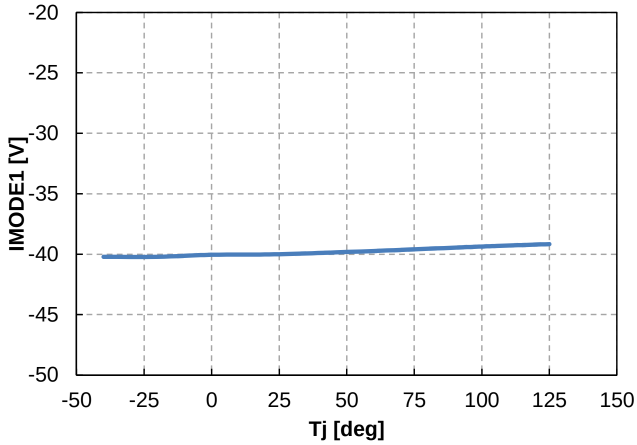




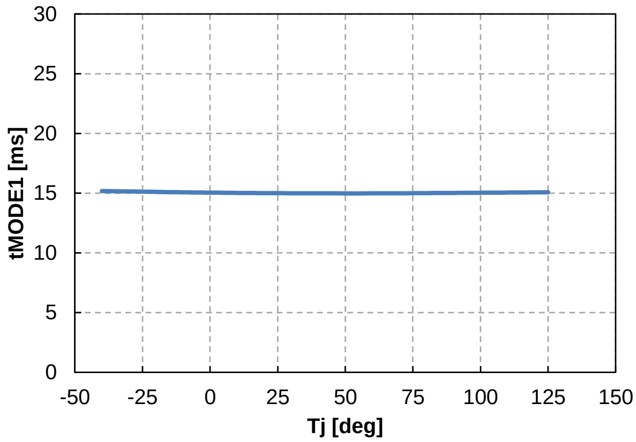
High-side quiescent current



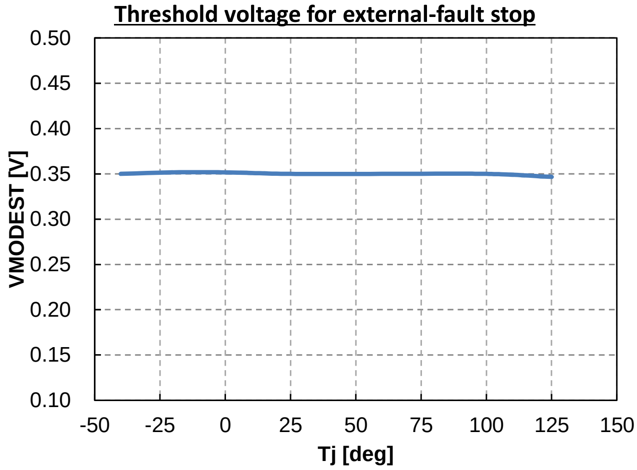
Mode selection source current



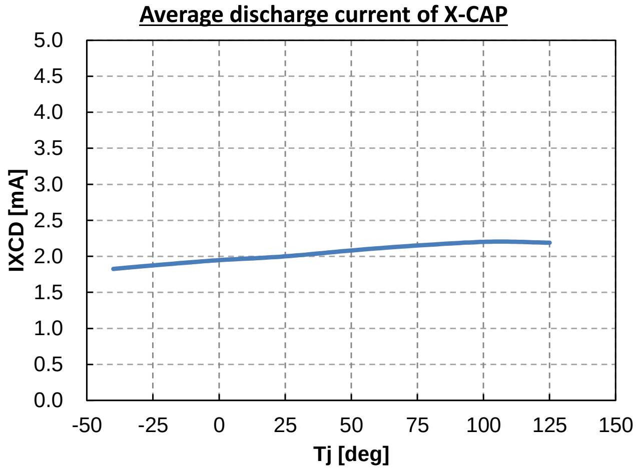
Mode selection time



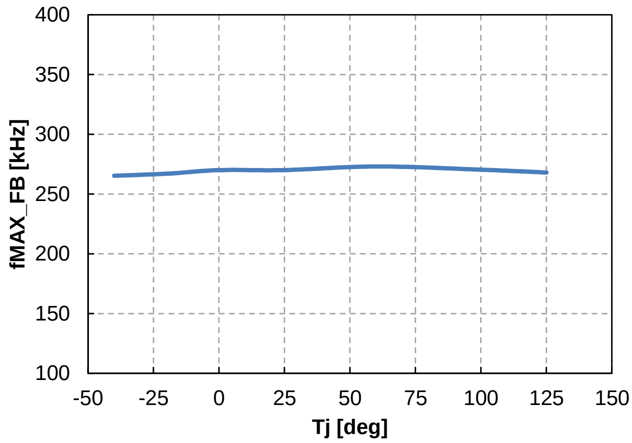
Threshold voltage for external-fault stop



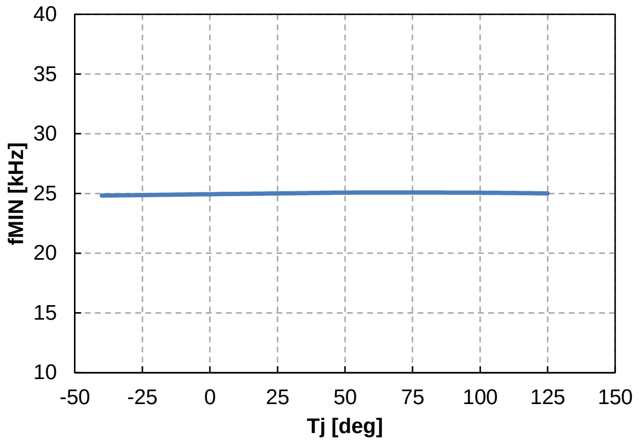
Average discharge current of X-CAP



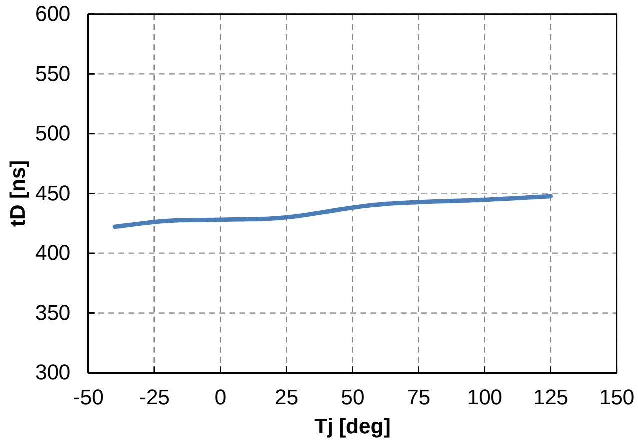
Maximum oscillation frequency



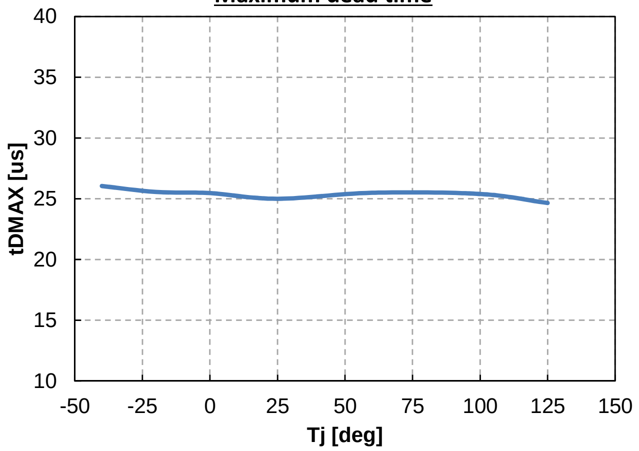
Minimum oscillation frequency



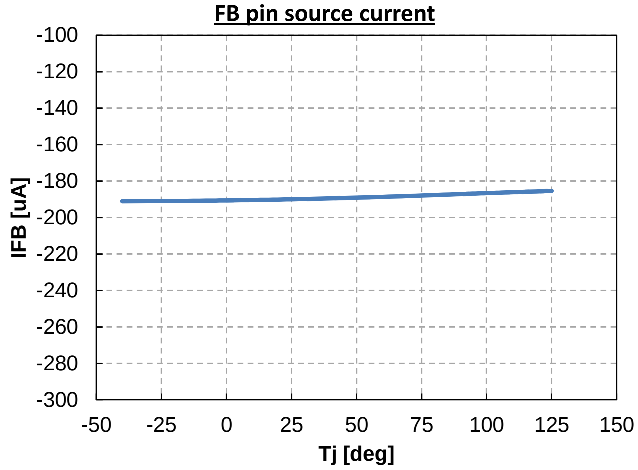
Minimum dead time



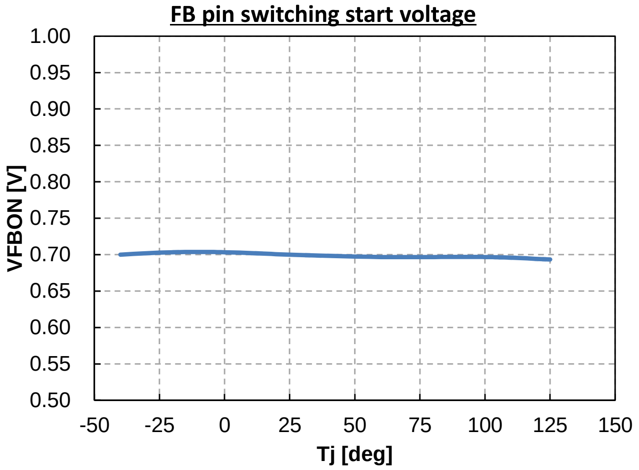
Maximum dead time



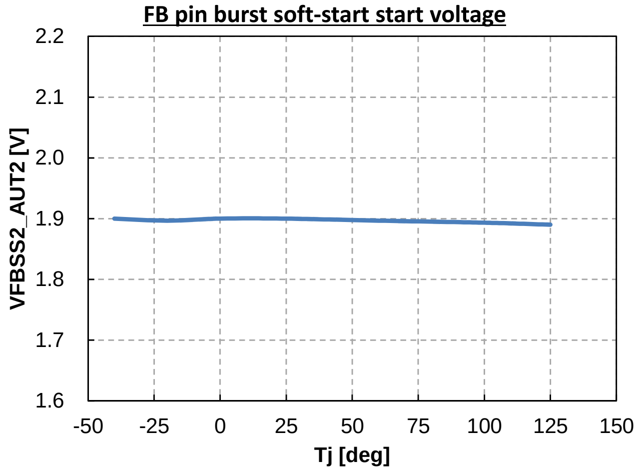
FB pin source current

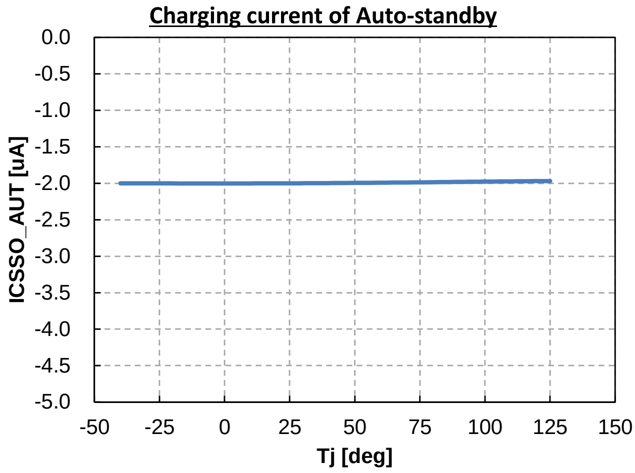


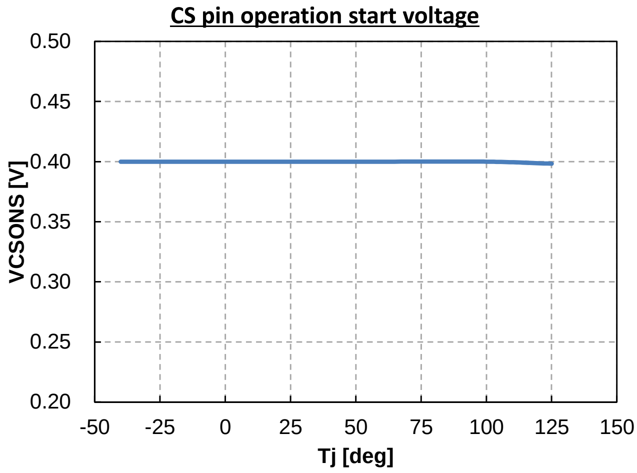
FB pin switching start voltage

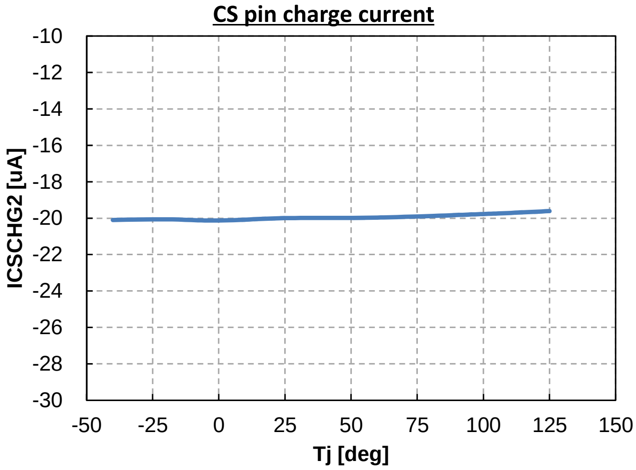


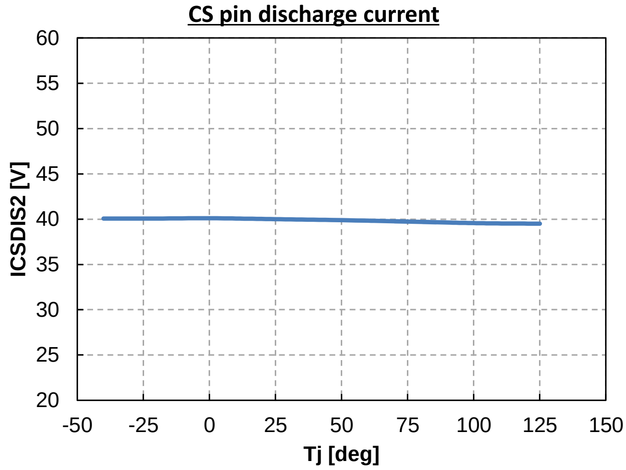
FB pin burst soft-start start voltage

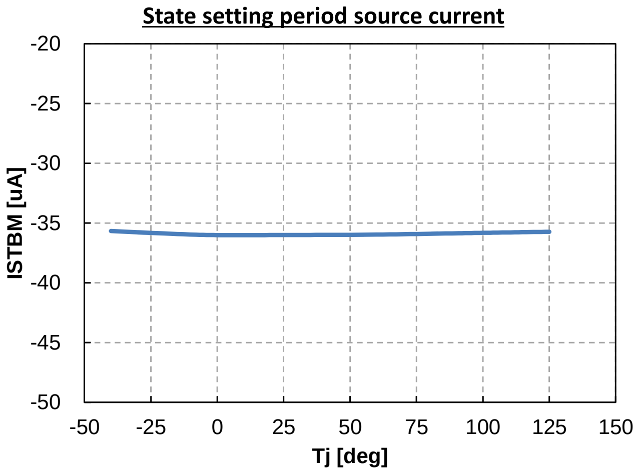


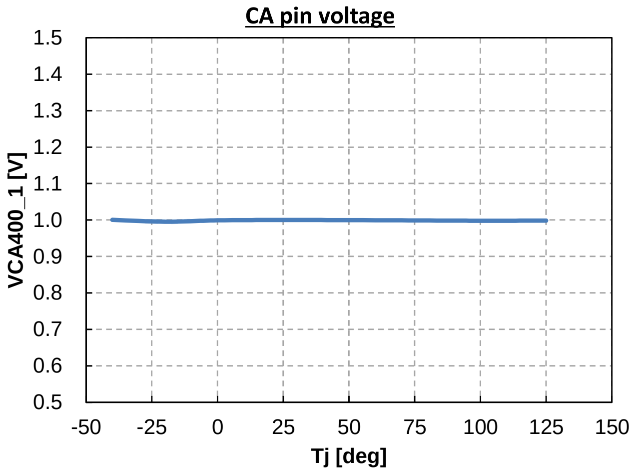

Charging current of Auto-standby
ICSSO_AUT [uA]
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-50
-25
0
25
50
75
100
125
150
Tj [deg]

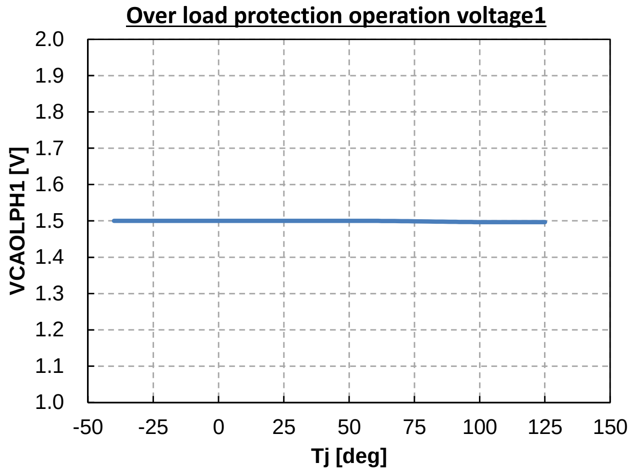

CS pin operation start voltage
VCSONS [V]
0.50
0.45
0.40
0.35
0.30
0.25
0.20
-50
-25
0
25
50
75
100
125
150
Tj [deg]

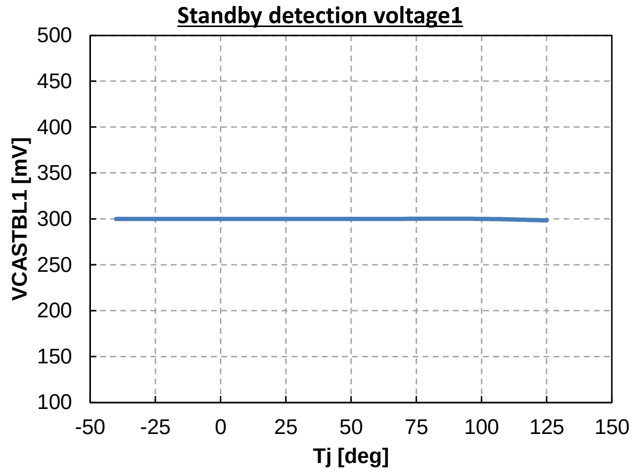

CS pin charge current
ICSCHG2 [uA]
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-50
-25
0
25
50
75
100
125
150
Tj [deg]

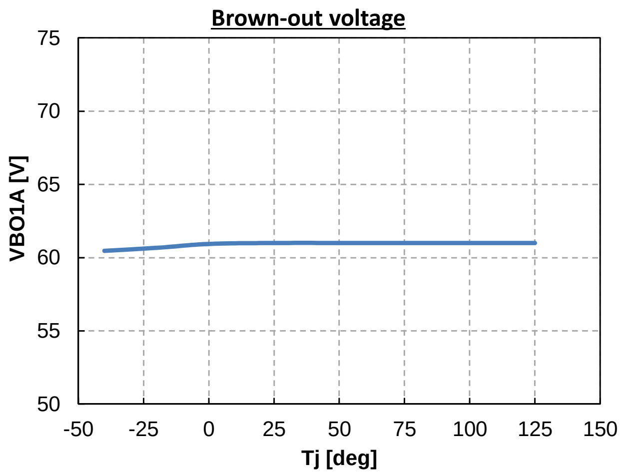

CS pin discharge current
ICSDIS2 [V]
60
55
50
45
40
35
30
25
20
-50
-25
0
25
50
75
100
125
150
Tj [deg]

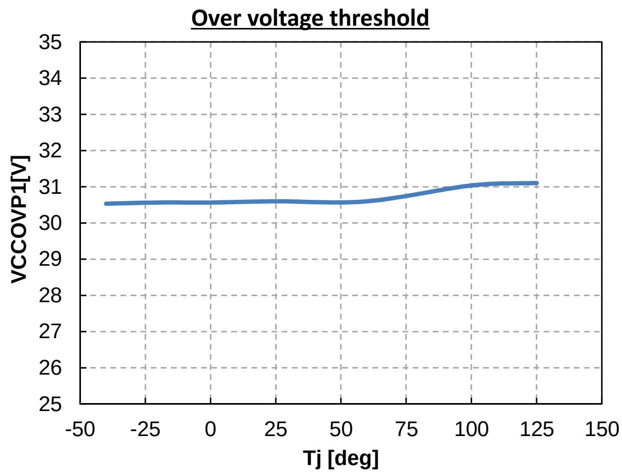

State setting period source current
ISTBM [uA]
-20
-25
-30
-35
-40
-45
-50
-50
-25
0
25
50
75
100
125
150
Tj [deg]

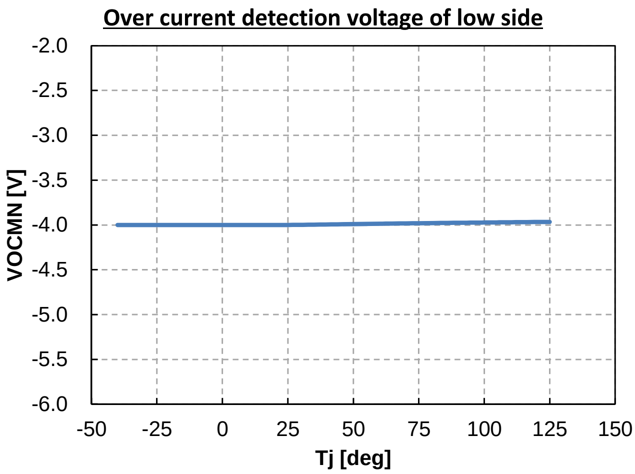

CA pin voltage
VCA400_1 [V]
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
-50
-25
0
25
50
75
100
125
150
Tj [deg]

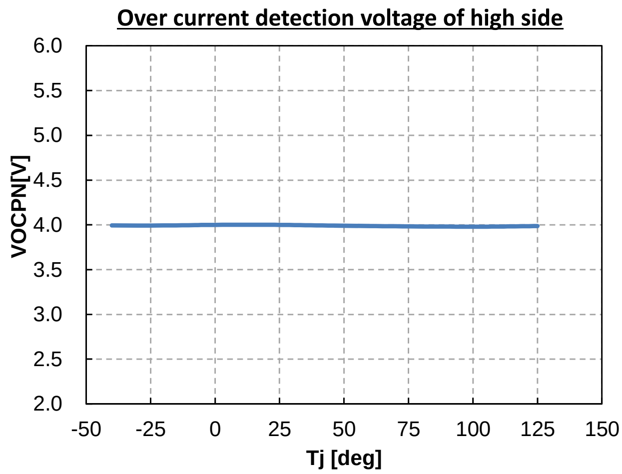

Over load protection operation voltage1
VCAOLPH1 [V]
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
-50
-25
0
25
50
75
100
125
150
Tj [deg]

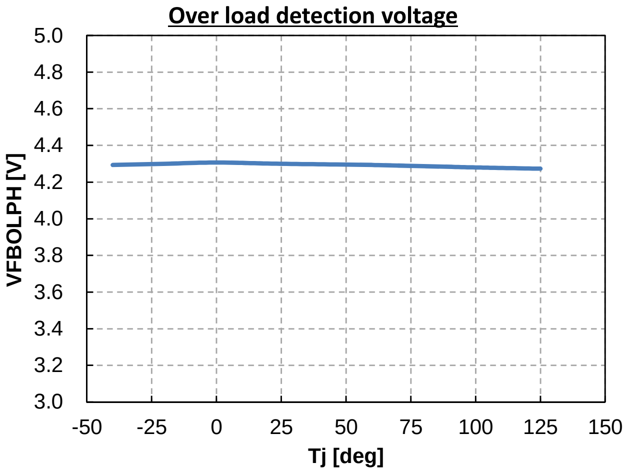

Standby detection voltage1
VCASTBL1 [mV]
500
450
400
350
300
250
200
150
100
-50
-25
0
25
50
75
100
125
150
Tj [deg]

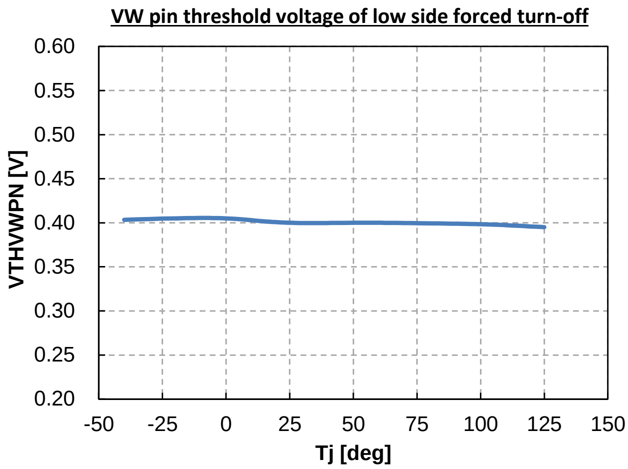

Brown-out voltage
VBO1A [V]
75
70
65
60
55
50
-50
-25
0
25
50
75
100
125
150
Tj [deg]

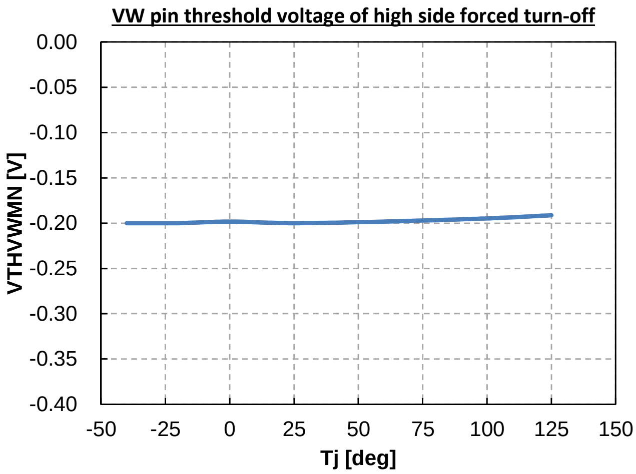

Over voltage threshold
VCCOVP1[V]
35
34
33
32
31
30
29
28
27
26
25
-50
-25
0
25
50
75
100
125
150
Tj [deg]

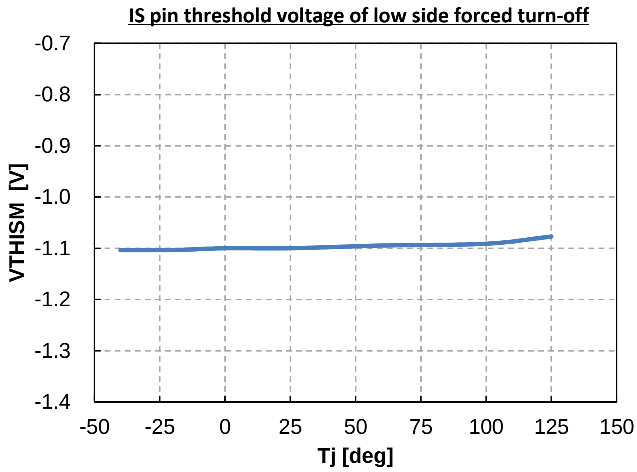

Over current detection voltage of low side
VOCMN [V]
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
-50
-25
0
25
50
75
100
125
150
Tj [deg]

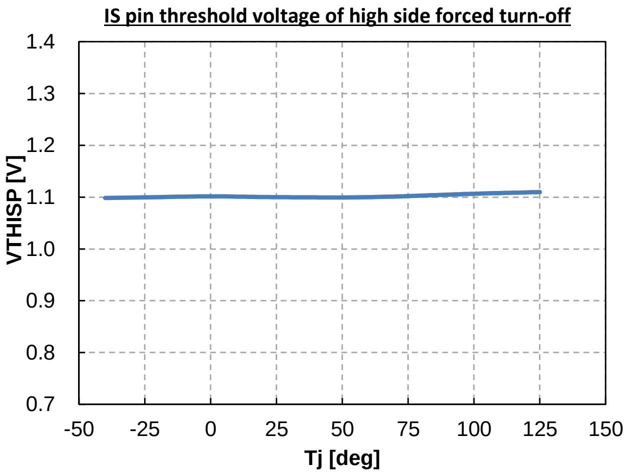

Over current detection voltage of high side
VOCPN[V]
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
-50
-25
0
25
50
75
100
125
150
Tj [deg]


Over load detection voltage
VFBOLPH [V]
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
-50
-25
0
25
50
75
100
125
150
Tj [deg]


VW pin threshold voltage of low side forced turn-off
VTHVWPN [V]
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
-50
-25
0
25
50
75
100
125
150
Tj [deg]


VW pin threshold voltage of high side forced turn-off
VTHVWMN [V]
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-50
-25
0
25
50
75
100
125
150
Tj [deg]


IS pin threshold voltage of low side forced turn-off
VTHISM [V]
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-50
-25
0
25
50
75
100
125
150
Tj [deg]


IS pin threshold voltage of high side forced turn-off
VTHISP [V]
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
-50
-25
0
25
50
75
100
125
150
Tj [deg]

8. LLC current resonant converter

8-1. LLC current resonant converter

FA6B20N is the control IC for the LLC current resonant converter. The LLC current resonant converter has the circuit configuration as shown in Fig. 1 and reduces the transformer's magnetizing inductance and the variation width of switching frequency against load change. When the variation width of switching frequency is reduced, the accuracy of output voltage is improved. If this LLC current resonant converter is used for a multi-output converter, output voltage regulation against the load change of the other output, namely cross-regulation, can be improved.

Since the LLC resonant converter is driven by half-bridge circuit, it requires a floating high-side driver circuit in addition to a low-side driver circuit.

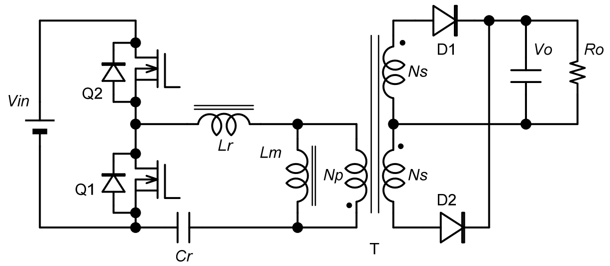


Fig. 1 LLC Current Resonant Converter Circuit

8-2. Operation of LLC current resonant converter

Fig. 1 shows the circuit of the LLC current resonant converter. The high side and low side switch elements Q_1 and Q_2 turns on and off alternately at the equal duty ratio of 50%. In Fig. 1, C_r is resonant capacitor, L_r is leakage inductance for resonant, T is transformer, and L_m is a magnetizing inductance of T. N_p is the winding number of transformer's primary winding and N_s is that of transformer's secondary winding.

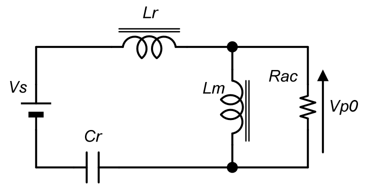


Fig. 2 Equivalent Circuit of LLC Circuit

Fig. 2 shows the equivalent circuit of LLC converter. The output voltage is indicated as V_{p0}, converted to the primary-side. The load resistance R_0 is indicated as the AC equivalent resistance R_{ac} as shown in Formula (8.1).

$$R_{ac} = \frac{8}{\pi^2} n^2 \frac{V_0}{I_0} = \frac{8n^2}{\pi^2} R_0 \qquad (8.1)$$

where n is the turn ratio of the transformer and indicated in Formula (8.2).

$$n = \frac{N_P}{N_S} \qquad (8.2)$$

The input-output voltage ratio, called voltage gain, can be obtained as Formula (8.3) using the equivalent circuit.

$$\frac{V_{P0}}{V_S} = \frac{1}{1 + \frac{L_r}{L_m}(1 - \frac{\omega_0^2}{\omega^2}) + jQ(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega})} \qquad (8.3)$$

where ω is the angular frequency, and the respective parameters are indicated in the following formulas.

$$\omega = 2\pi f_S \qquad (8.4)$$

$$\omega_0 = \frac{1}{\sqrt{L_r C_r}} \qquad (8.5)$$

$$Q = \sqrt{\frac{L_r}{C_r}} \frac{1}{R_{ac}} \qquad (8.6)$$

The LLC current resonant converter in Fig. 1 is a half-bridge converter and the input voltage of equivalent circuit shown in Fig. 2 becomes a half as follows:

$$V_S = \frac{V_{IN}}{2} \qquad (8.7)$$

Example:

When the conditions are as follows, the calculation results are shown in Fig. 3 and 4.

• Input voltage V_{IN}	400V
• Output voltage V_O	24V
• Output current I_O	8A (Ro=3Ω)
• Turn ratio of transformer n	9
• Magnetizing inductance L_m	700μH
• Leakage inductance L_r	100μH
• Resonant capacitor C_r	0.033μF

Fig. 3 shows the voltage gain against the switching frequency f_s found with Formula (8.3), and the load resistance R_o is variable. When f_s increases, the voltage gain also increases and begins to decrease gradually after reaching the maximum.

The resonant frequency f_o is decided by Formula (8.5), and voltage gain becomes 1 when f_s equals f_o.

The LLC converter is operated within the frequency range between maximum voltage gain frequency and f_o. In other words, the LLC resonant converter operates in the boost mode, in which the voltage gain is always larger than 1.

As shown in Fig. 3, when the load resistance R_o becomes larger, the voltage gain becomes larger. In addition, when the load resistance R_o is smaller, the maximum gain frequency becomes slightly higher.

Fig. 4 also shows the voltage gain against the switching frequency f_s found with Formula (8.3), and the transformer magnetizing inductance L_m is variable. The voltage gain becomes larger when L_m is smaller. In addition, when L_m is larger, maximum voltage gain frequency becomes lower.

Therefore, when the input voltage is lowest, find the voltage gain and decide L_m so that the output voltage can get the rated value.

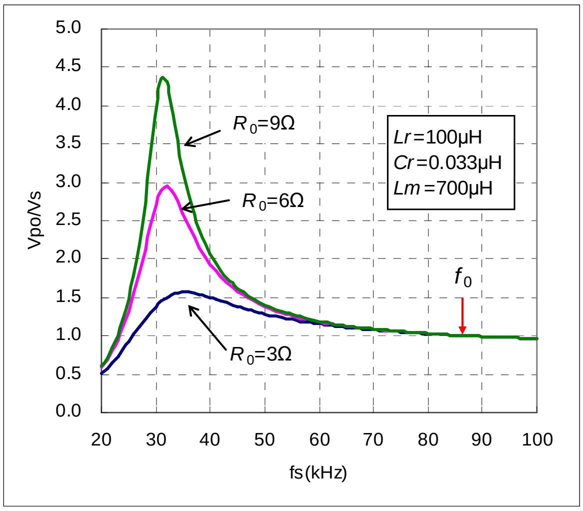


Fig. 3 Output to Input Voltage Characteristics

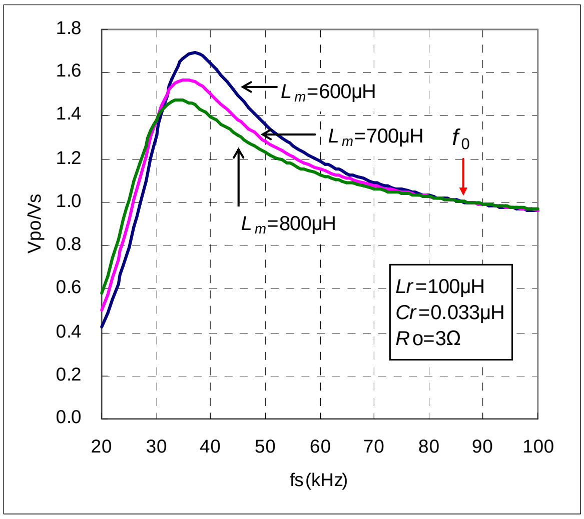


Fig. 4 Output to Input Voltage Characteristics

8-3. Design of transformer for LLC current resonant converter

As described above, the LLC current resonant converter operates in the boost mode and the voltage gain is decided so that it operates in the boost mode even when the input voltage is maximum. At first, seek the winding number of the secondary winding and then decide the winding number of the primary winding. Since the resonant frequency f_o becomes the maximum switching frequency, decide it beforehand within the range where it does not exceed the maximum frequency of this IC.

(1) Use the following formula (8.8) to find the winding number Ns of the transformer's secondary winding.

$$N_S = \frac{(V_0 + V_F)T_{on}}{2A_e B_m} \qquad (8.8)$$

where V_o is the output voltage [V], V_F is the forward voltage drop [V] of the rectifier diode, T_{on} is the maximum ON time (equal to 1/2 of the switching period at the minimum switching frequency) of the switch element, A_e is the effective cross-section area [cm2] of the transformer core, and B_m is the unsaturated value of the core's magnetic flux density [T].

(2) Use the formula (8.9) to find the ratio of the transformer's primary and secondary winding numbers n in order to operate the converter in the boost mode even when the input voltage is maximum. V_s is the value at the maximum input voltage.

$$n = \frac{N_P}{N_S} \geq \frac{V_S}{(V_0 + V_F)} \qquad (8.9)$$

(3) Use the formula (8.10) to find the winding number of the transformer's primary winding.

$$N_P = nN_S \qquad (8.10)$$

(4) Find the leakage inductance L_r.

In this converter, the leakage inductance of the transformer is used as the inductor for resonance. From winding number N_p of the primary winding, leakage inductance L_r for the primary winding can be found.

Connecting an additional resonant inductor separately from a transformer does not recommend.

(5) Decide the resonant capacitor C_r.

Use Formula (8.5) to calculate the resonant capacitor C_r from the resonant frequency f_o and L_r.

(6) Decide the magnetizing inductance L_m.

Find the voltage gain so that the output voltage can get the rated value, and decide L_m when the input voltage is minimum. Under this condition, the switching frequency is the minimum. Since the primary inductance of the transformer includes the leakage inductance, primary inductance is equal to sum of L_m and a half of L_r.

Use the formula (8.11) to calculate the gap l_g of the transformer core.

$$l_g = \frac{\mu_0 A_e N_P^2}{L_m} - \frac{l_e}{\mu_C} \qquad (8.11)$$

where μ_0 is the absolute permeability of vacuum (=4π × 10^{-7} H/m), μc is the amplitude permeability (=3000), and le is the effective magnetic path (mm).

Example:

An example of transformer design is shown below:

- Input voltage V_{IN} 360V (min 340V to max 390V)
- Output voltage V_o 24V
- Output current I_o 8A (Ro=3Ω)
- Used transformer EER35
  A_e=107.0 mm²
  l_e=90.8 mm
  B_m=0.35 (T)
- Resonant frequency approx. 100kHz
- Minimum switching frequency 60kHz (Ton=8.3μs)
- Forward voltage drop of rectifier diode V_F=1.0V

(1) Winding number of transformer's secondary winding N_s (Formula (8.8))

$$N_S = \frac{(V_0+V_F)T_{on}}{2A_eB_m} = \frac{(24+1)\times 8.3}{2\times 107\times 0.25} = 3.88 \Rightarrow 4$$

(2) Turn ratio n of transformer (Formula (8.9))

$$n = \frac{N_P}{N_S} \geq \frac{V_S}{(V_0+V_F)} = \frac{195}{(24+1)} = 7.8$$

(3) Winding number N_p of transformer's primary winding (Formula (8.10))

$$N_P = nN_S = 7.8\times 4 = 31.2 \Rightarrow 32$$

Accordingly, n=8

(4) Calculation of transformer's leakage inductance L_r

Since the leakage inductance is 72(nH) per turn in the EER35 transformer, the leakage inductance becomes 73.7 (μH) (=322 × 72nH) when the winding number (N_p) of the primary winding is 32.

(5) Decide the resonant capacitor C_r.

When f_o=100kHz and L_r=73.7 (μH) are substituted into the formula (8.5) to find C_r, 0.033μF is obtained.

(6) Decide the magnetizing inductance L_m

Find L_m so that the output voltage will be the rated value when the input voltage is minimum. Since the input voltage is 340V(min), the input-to-output voltage ratio is calculated as follows using the transformer turn ratio.

$$\frac{V_{P0}}{V_S} = \frac{V_0+V_F}{\frac{N_S}{N_P}\frac{V_{IN}}{2}} = \frac{24+1}{\frac{4}{32}\frac{340}{2}} = 1.17 \Rightarrow 1.2$$

Therefore, when the switching frequency is at the minimum (fs=60kHz in this case), find Lm which provides the voltage gain of 1.2 or higher using the formula (8.3).

As a result, if Lm is 600μH or less, it is acceptable. In the case of Lm=600μH, when the formula (8.11) is used to find the gap lg of transformer core, the value of about 0.2mm can be obtained as calculated below.

$$l_g = \frac{\mu_0 A_e N_P^2}{L_m} - \frac{l_e}{\mu_C} = \frac{4\pi\times 10^{-7}\times 107\times 32^2}{600} - \frac{90.8\times 10^{-3}}{3000} \cong 0.2\times 10^{-3}$$

8-4. Capacitive mode

Fig. 5 shows the voltage gain against the switching frequency fs in the LLC current resonant converter. The operation mode differs between lower and higher frequency area than maximum gain frequency as shown in Fig. 5.

The area where the frequency is lower than the maximum voltage gain frequency is called capacitive region and short current may flows through the high and low side switches of the half-bridge circuit at transition (it is called shoot through). In this case, the MOSFET may be damaged. Therefore, usually the converter is operated in the region where frequency is higher than the maximum voltage gain frequency gain not to cause shoot through.

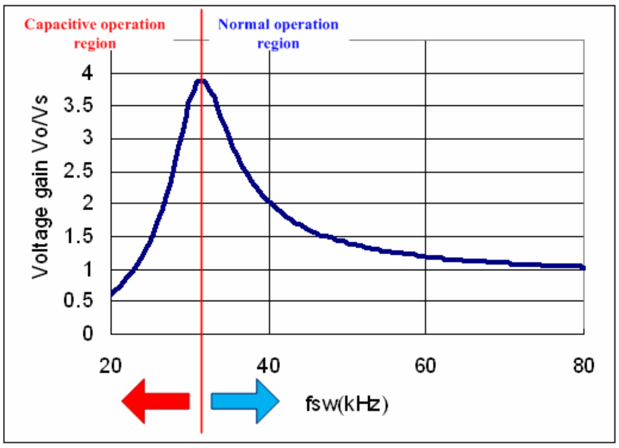


Fig. 5 Operation mode of LLC

(1) Operation in capacitive region

If the frequency becomes low, capacitive mode operation is started. While Q_1 is ON, the current I_{D1} starts decreasing after reaching the maximum value, eventually the resonance current I_{cr} turns from positive to negative and I_{D1} also turns from positive to negative. (d)

When Q_1 is turned off in this status, current flows through the parasitic diode of Q_1. When the opposing Q_2 is turned on, the parasitic diode of Q_1 enters the status of reverse recovery and may be damaged. (c)

While Q_2 is ON, the current I_{D2} starts decreasing after reaching the maximum value, and eventually the resonance current I_{cr} turns from negative to positive, and I_{D2} turns from positive to negative. (b)

If Q_2 is turned off in this state, current flows through the parasitic diode of Q_2. When the opposing Q_1 is turned on, the parasitic diode of Q_2 enters the status of reverse recovery and may be damaged. (a)

(2) Operation in the normal region

Generally the converter is used in the following operating conditions.

While Q_1 is ON, the current I_{D1} starts decreasing after reaching the maximum value. (a)

When Q_1 is turned off while I_{D1} is in the positive status, current flows through the Q_2 side. The opposing Q_2 is turned on, and the resonance current Icr changes continuously. (b)

While Q_2 is ON, the current I_{D2} turns from negative to positive and starts decreasing after reaching the maximum value. (c)

When Q_2 is turned off while I_{D2} is in the positive status, current flows through the Q_1 side. The opposing Q_1 is turned on, and the resonance current I_{cr} changes continuously. (d)

By repeating this operation, the resonance current Icr can be generated.

In other words, before the currents I_{D1} and ID2 of Q_1 and Q_2 become negative, MOFET is turned off and operation is switched to the opposing MOSFET. Therefore, operation is continued without any shoot through.

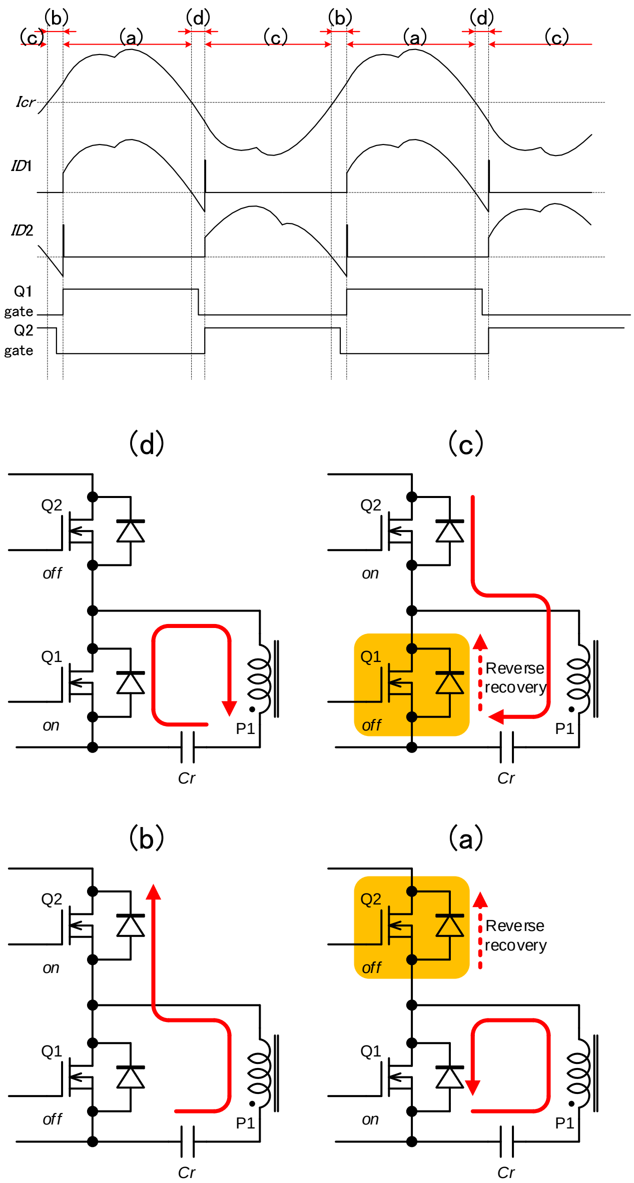


Fig. 6 Operation waveform in capacitive region

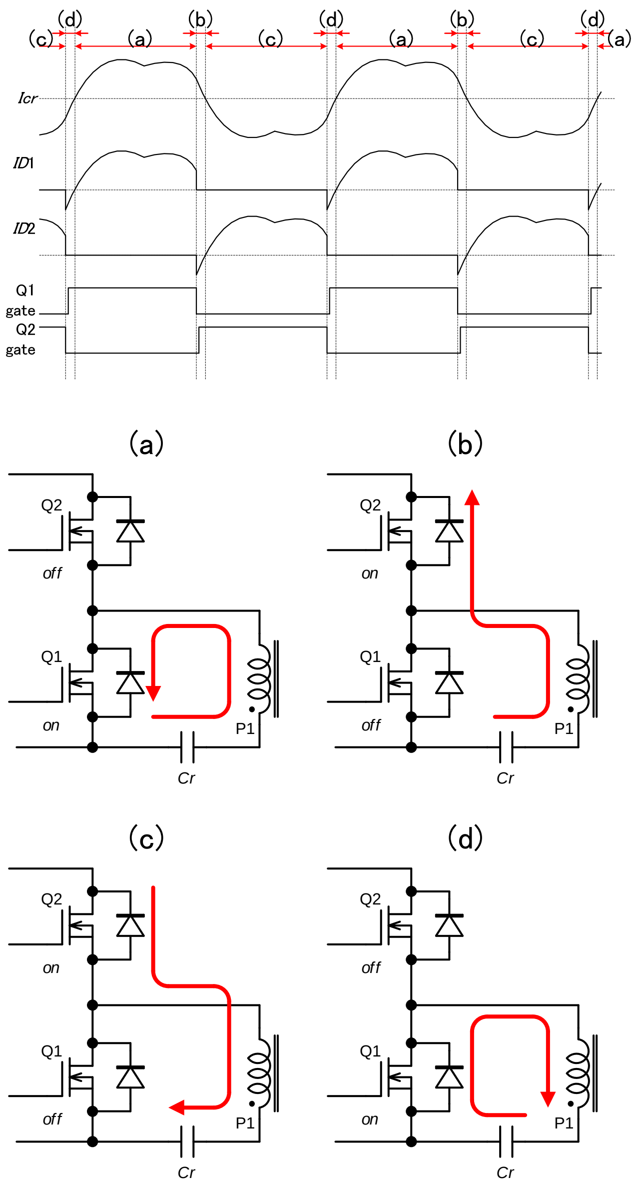


Fig. 7 Normal operation waveform

9. Description of the function
(The values in the following description are typical values unless otherwise specified.)

(1) Protection functions list

Table 1 lists the protection function included in FA6B20N. All protection functions without Mode selection resistor open detection are auto recovery type.

Table 1: Protection functions list

Protection function	FA6B20N	Protection function	FA6B20N
CA pin overload protection	Automatic recovery	MODE pin protection by external signal	Automatic recovery
FB pin overload protection	Automatic recovery	Thermal shutdown	Automatic recovery
IS pin overcurrent protection	Automatic recovery	MODE pin mode selection resistor open detection	Latch
VCC pin overvoltage protection	Automatic recovery		
VH pin brown-in / out	Automatic recovery	VCC voltage drop protection	Automatic recovery

Note: The overload, overcurrent, overvoltage and Vcc voltage drop protection functions allow switching to be resumed after it is suspended for a specified period of time. In case of other protection functions (VH pin brown-in/out, thermal shutdown or MODE pin protection by external signal), switching is stopped when temperature or VH pin voltage exceeds the threshold value set within the IC, and switching is resumed when the value decreases within the permissible range.

(2) Oscillation frequency

The LLC current resonance converter is controlled by switching frequency modulation (SFM). Therefore, the IC has FB pin which is input the feedback signal from the secondary output voltage and an oscillator, which controls the switching frequency according to the feedback signal. The oscillation frequency changes according to the FB pin voltage as feedback and the CS pin voltage as soft-start/end control. The oscillation frequency is decided as below in each operating mode.

1. In normal operation mode, it is decided higher one between the frequency set by FB pin or CS pin. However, CS pin voltage goes up to internal bias voltage after soft-start period and the frequency is decided FB pin voltage.
2. In low standby mode, FB pin voltage is disabled to control the frequency. The frequency is decided only by CS pin voltage. (See page 31 for details)
3. The oscillation frequency in the period of soft start at start up is decided based on the curves of Fig. 10.

Low standby mode

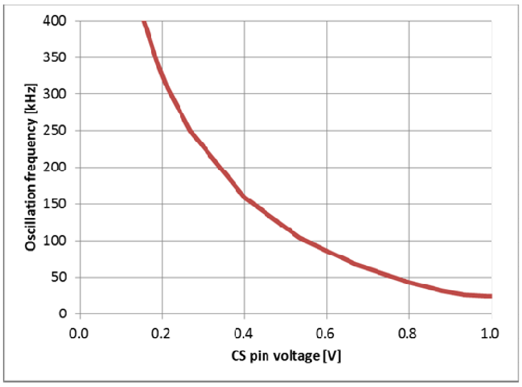


Fig. 8 VCS vs. Oscillation frequency

Normal mode

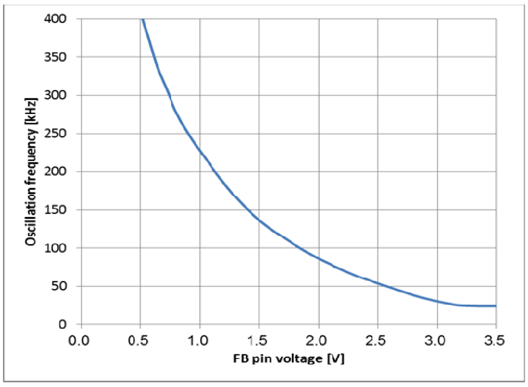


Fig. 9 VFB vs. Oscillation frequency

Soft start at start up

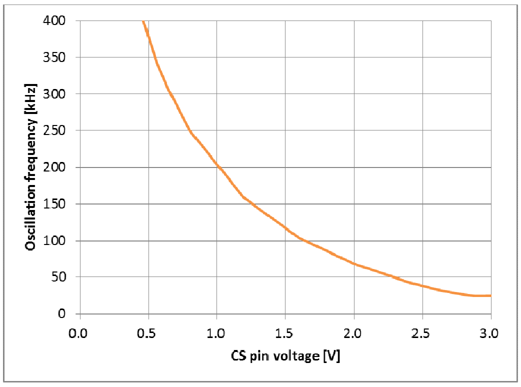


Fig. 10 VCS vs. Oscillation frequency

(3) Soft start function

Since the CS pin voltage increases charging the capacitor connected to the CS pin, the frequency gradually decreases from high frequency depending on the CS pin voltage, which is called soft start.

Both the CS pin voltage and the FB pin voltage are kept in the GND level before startup. Since output voltage is insufficient just after the startup, the FB pin voltage goes up to the internal bias voltage (5V). Therefore, the oscillation frequency is decided by CS pin voltage at soft start period.

Soft start/end operation is also enabled with CS pin voltage in burst mode operation, which will be described later.

(4)Input power detection

This IC has an input power detection function. Operating mode is switched automatically depending on input power. Fig. 11 shows the peripheral circuits of the input power detection function and Fig. 12 shows the characteristics of CA pin voltage vs. IS pin voltage.

As shown in Fig. 11, the input power detection function monitors high side MOSFET current as input current. The current is detected by the IS pin and the detected current information is smoothed by the capacitor connected between the CA pin and GND. Therefore, a voltage proportional to the input current is output on the CA pin. The input voltage of the LLC part is constant due to PFC circuit and the input power can be detected by input current detection.

(Note) Input power detection function is designed on the premise that PFC is used. We does not recommend to use without PFC.

With the input power detecting function, the IC detects decreased load power and switches into the low standby mode (burst operation) automatically without external signal. The IC also detects overload condition and enters into protection mode.

As shown in Fig. 12, the conversion gain from IS pin to CA pin is switched in order to widen the CA pin voltage control range. The voltage characteristic has hysteresis.

- When load is increased, if the CA pin voltage rises to 1.45V, the gain is switched and the voltage is drops to 0.725V
- When load is decreased, if the CA pin voltage drops to 0.6V, the gain is switched and the voltage rises to 1.2V.

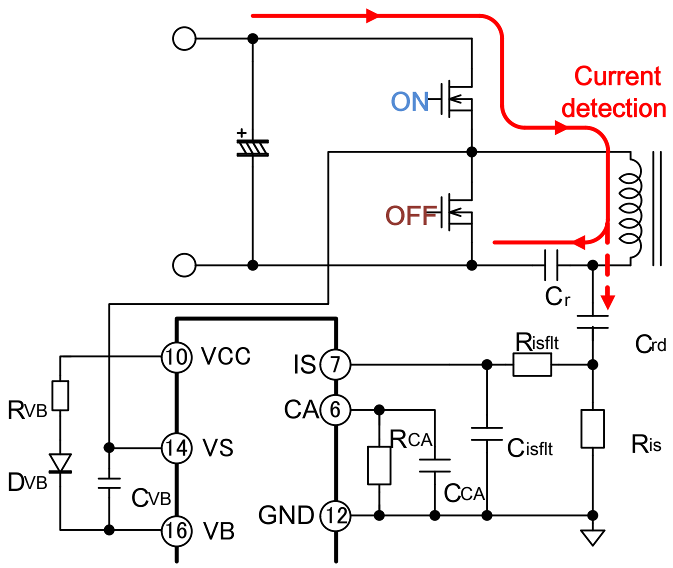
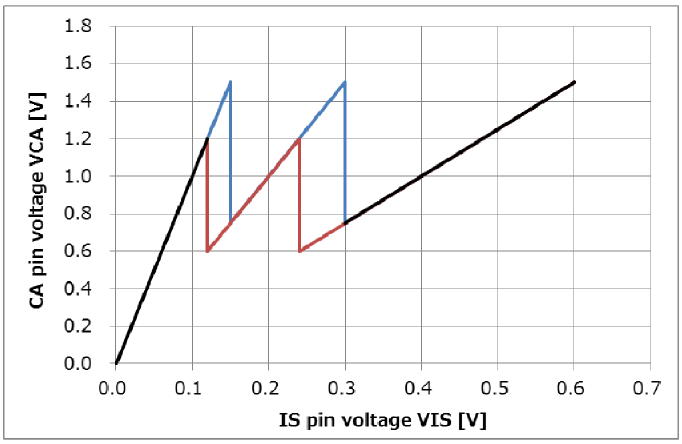


Fig. 11 Current detection function circuit diagram



Condition: IS pin, DC voltage is applied
VW pin, 50% Duty cycle

Fig. 12 CA pin voltage vs. IS pin voltage

(5) Mode selection function

At start up, the IC selects some operating mode according to the resistors of STB pin- GND and MODE pin-GND.
The following function can be selected by the mode selection function.

Mode selection by STB pin

1. Switch method between normal mode and low standby mode: “Auto standby operation” and “Standby operation by external signal” are selectable.
2. CA pin OLP threshold voltage: The threshold of CA pin OLP is selectable.

Table 2: Standby pin resistor and mode selection

Mode	STB pin	Switch method	CA pin OLP
A	33kΩ	Standby by external signal	1.5V
B	82kΩ	Auto standby	1.5V
C	300kΩ	Auto standby	3.0V

“Auto standby operation” and “Standby operation by external signal”

As for switch method between normal mode and low standby mode, “Auto standby operation” and “Standby operation by external signal” are selectable.
Fig. 14 shows the circuit diagram of “Auto standby operation” and “Standby operation by external signal”.

In “Auto standby operation”, operating mode is switched automatically when the CA pin voltage reaches the threshold voltage of mode switch. In this operation, switch signal is not necessary and external components can be reduced. In addition, if the “Auto standby operation” is selected, STB pin outputs line voltage and load condition signal. If the signal is input to the RT pin of fuji CRM PFC IC “FA1A60N”, PFC operating mode (continuous, burst or stop) can be also controlled and the efficiency of PSU at light load can be improved.

In “Standby operation by external signal”, operating mode is switched by external signal connected to STB pin. Fig. 13 shows an example circuit in which operating mode is switched at the same time when PFC is stopped at light load.

In case of “Auto standby operation”, PFC should be operated in any condition because the CA pin which detects input power is affected by LLC part input voltage. We do not recommend “Auto standby operation” with PFC stop at light load.

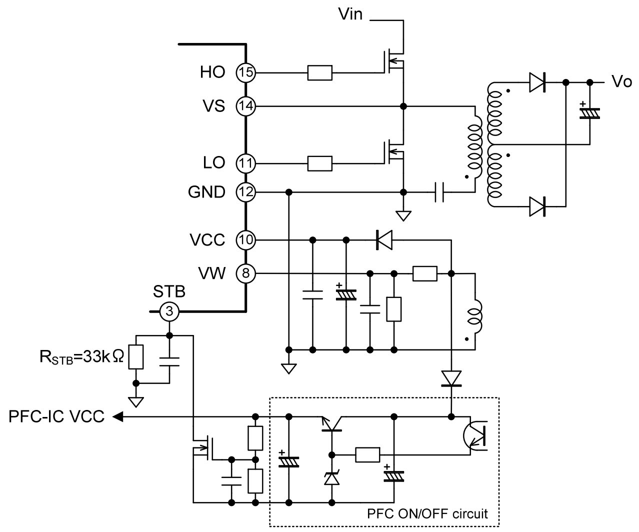


Fig. 13 Circuit diagram for external signal

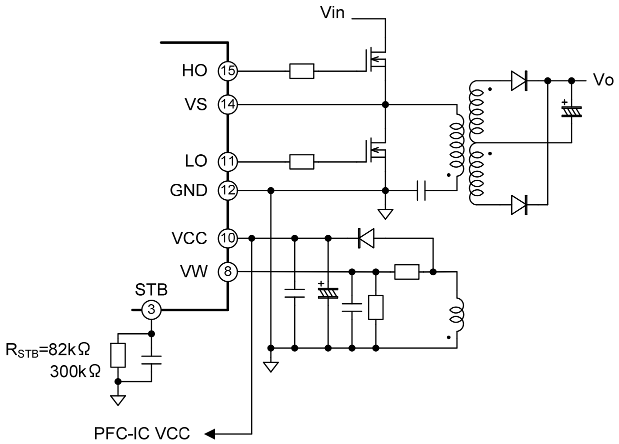


Fig. 14 Circuit diagram for auto standby

MODE selection by MODE pin

1. Threshold of CA pin voltage between normal mode and low standby mode: Threshold of CA pin voltage between normal mode and low standby mode is selectable from 3 voltage. (In “auto standby operation” only)
2. Threshold of CA pin at which CS pin charge/discharge current is changed: If load is increased in low standby mode, transformer may generate audio noise based on the burst frequency or large input current. To prevent audio noise in low standby mode with large load, if load is increased, IC changes CS pin charge/discharge current so that the soft start/end period will be extended. The threshold of CA pin at which CS pin charge/discharge current is changed is selectable.
3. VW pin threshold for forced turn off while the delay period to release CS clamp: In auto standby operation, IC switches operation mode from low standby to normal with 600us delay. In delay period, CS pin voltage is clamped to 1V and switching operation is controlled by VW pin forced turn off in order to prevent drop of the output voltage. Threshold of VW pin forced turn off to control switching operation can be selected from 3 voltage.

Table 3: MODE pin resistor and mode selection

<table>
<tr><th rowspan="2">Mode</th><th rowspan="2">MODE pin</th><th colspan="2">CA pin threshold for switch between normal and standby</th><th colspan="2" rowspan="2">CA pin threshold for CS pin charge /discharge change</th><th colspan="2">VW pin forced turn off threshold while the delay period to release CS clamp.</th></tr>
<tr><th>To low standby mode</th><th>To normal mode</th><th>Low side</th><th>High side</th></tr>
<tr><td>A</td><td>15kΩ</td><td rowspan="3">0.30V</td><td rowspan="3">0.35V</td><td rowspan="3">0.20V</td><td rowspan="3">0.25V</td><td>-1.2V</td><td>1.4V</td></tr>
<tr><td>B</td><td>24kΩ</td><td>-1.0V</td><td>1.2V</td></tr>
<tr><td>C</td><td>36kΩ</td><td>-0.8V</td><td>1.0V</td></tr>
<tr><td>D</td><td>56kΩ</td><td rowspan="3">0.40V</td><td rowspan="3">0.45V</td><td rowspan="3">0.30V</td><td rowspan="3">0.35V</td><td>-1.2V</td><td>1.4V</td></tr>
<tr><td>E</td><td>82kΩ</td><td>-1.0V</td><td>1.2V</td></tr>
<tr><td>F</td><td>120kΩ</td><td>-0.8V</td><td>1.0V</td></tr>
<tr><td>G</td><td>180kΩ</td><td rowspan="3">0.60V</td><td rowspan="3">0.70V</td><td rowspan="3">0.40V</td><td rowspan="3">0.50V</td><td>-1.2V</td><td>1.4V</td></tr>
<tr><td>H</td><td>270kΩ</td><td>-1.0V</td><td>1.2V</td></tr>
<tr><td>I</td><td>390kΩ</td><td>-0.8V</td><td>1.0V</td></tr>
</table>

(6) Low standby mode

In principle, the efficiency of an LLC current resonant converter decreases at light load, and loss of several watts is generated under no load condition. Consequently, an auxiliary power supply is required in general as energy-saving measures in standby operation mode, which hinders downsizing.

In case of FA6B20N, operating mode is switched from the normal operation mode to the low-standby mode at light load, thereby achieving low standby power without using an auxiliary power supply.

(6-1)Low standby mode operation

In low standby mode, burst mode operation is achieved by repeating the Section 1 to 4 as shown in Fig. 15.

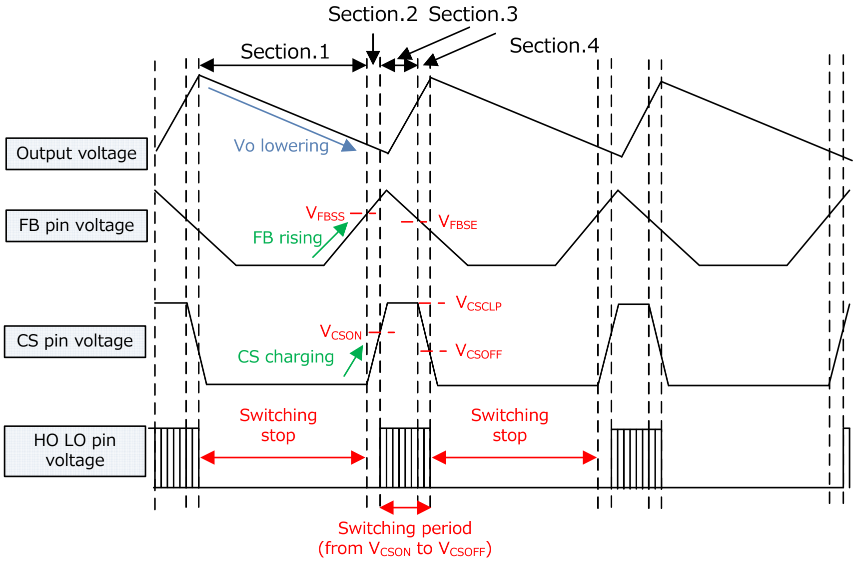


Fig. 15 Low standby mode operation waveform

Section.1

Switching stop period.
Output voltage drops gradually because switching stops. FB pin voltage rises according to the output voltage.

Section.2

When FB pin voltage rises to V_{FBSS}, CS pin start to charge capacitor and the CS pin voltage rises.

Section.3

When CS pin voltage rises to V_{CSON}, IC starts switching operation.
When CS pin voltage rises to V_{CSCLP}, CS pin voltage is clamped. (In auto standby mode)
By the switching operation, output voltage rises and FB pin voltage decreases.

Section.4

When FB pin voltage drops to V_{FBSE}, CS pin starts discharge the capacitor and the CS pin voltage drops. When CS pin voltage drops below V_{CSOFF}, IC stops switching operation.

(6-2) Switching frequency control by forced turn off function (In Auto standby operation only)

In auto standby operation, switching frequency is controlled by CS pin and VW pin at low standby mode. The details are described below.
(As for forced turn off function, please refer page 34)

1. During the soft start period, switching frequency is controlled by CS pin.
2. After the soft start, CS pin voltage clamped to 1V. When CS pin voltage is clamped, switching frequency is controlled by VW pin forced turn off function. By the forced turn off function, peak current of the secondary diode is limited. As the result, the loss of the secondary diode is reduced and the efficiency at low standby operation is improved. In addition, audio noise of transformer is also prevented because peak current of transformer is limited.
3. When output voltage rises, soft end is started and switching frequency is controlled by CS pin voltage.

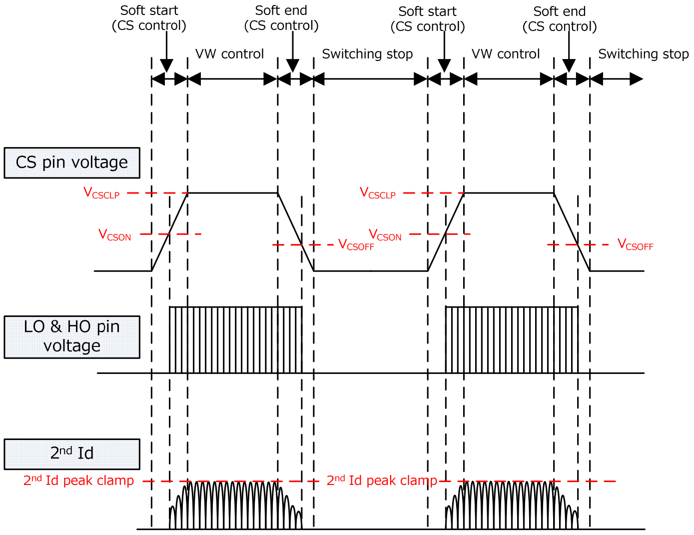


Fig. 16 Low standby mode at auto standby operation

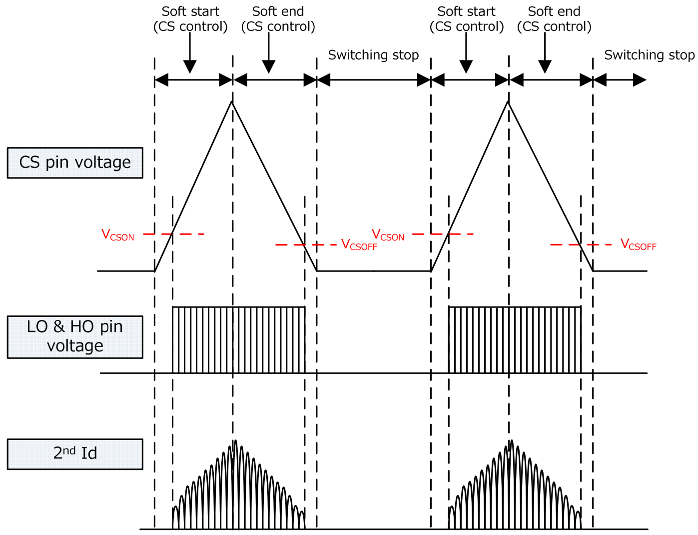


Fig. 17 Low standby mode at standby mode by external signal

(6-3) Switch sequence between normal mode and low standby mode

Switch sequence between normal mode and low standby mode are described on each method respectively.

(6-3-1) Auto standby operation

Fig. 18 shows the switch sequence of auto standby operation.

[Switch from normal mode to low standby mode]

When output power is decreased gradually, CA pin voltage also decreases according to the load power. When CA pin voltage drops below V_{CASL}, operating mode is switched from normal to low standby after the 108ms of delay.

If Fuji CRM PFC “FA1A60N” is used with this IC, PFC is also switched to burst mode by the communication signal from STB pin to RT pin of FA1A60N.

[Switch from low standby mode to normal mode]

When output power is increased gradually, CA pin voltage also increases according to the load power. When CA pin voltage rises above V_{CASH}, operating mode is switched from low standby mode to normal mode.

If Fuji CRM PFC “FA1A60N” is used with this IC, PFC is also switched to normal mode by the communication signal.

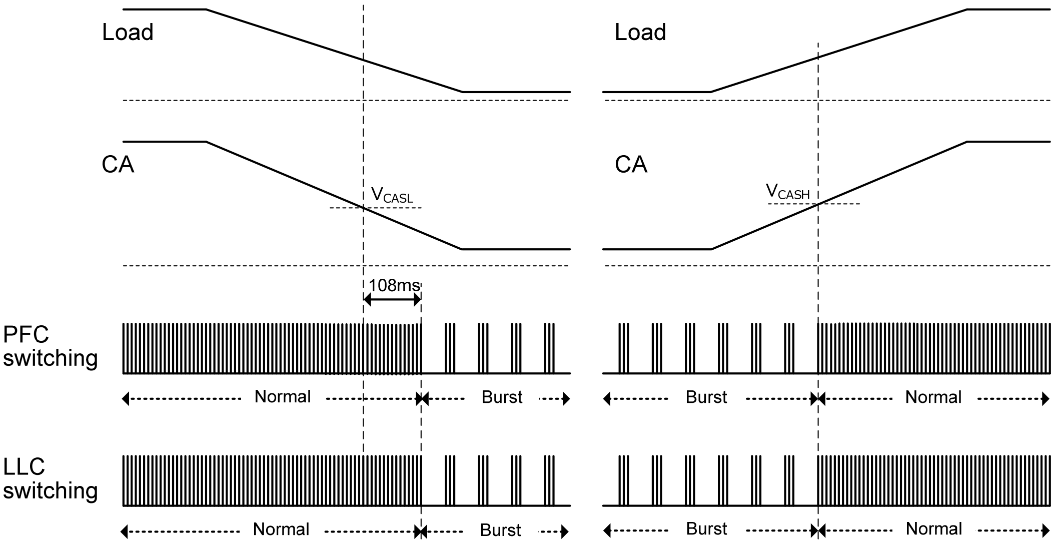


Fig. 18 Operating mode switch sequence (auto standby)

(6-3-2) Switch from low standby mode to normal mode by FB pin

Large capacitor is connected to CA pin in order to average primary input power. It causes delay time from load change to CA pin voltage rise. If load changes rapidly, switch to normal mode is delayed and output voltage may drop.

To prevent it, this IC has the function which switches to normal mode according to FB pin voltage rise. Even if CA pin voltage is below the threshold switching to normal mode, the IC switch to normal mode without delay at the time FB pin reaches to burst removal voltage of 2.5V.

However, if adjustment of each components is insufficient, operating mode may be switched to normal mode by FB pin below the output power where operating mode is switched from low standby to normal by CA pin. In such case, if CA pin voltage is below low standby mode threshold voltage after it is switched to normal mode by FB pin, operating mode is switched to standby mode again. Then operating mode switched to normal by FB pin. As the result, operating mode may repeats low standby mode and normal mode. Operation should be confirmed sufficiently when each component value is adjusted.

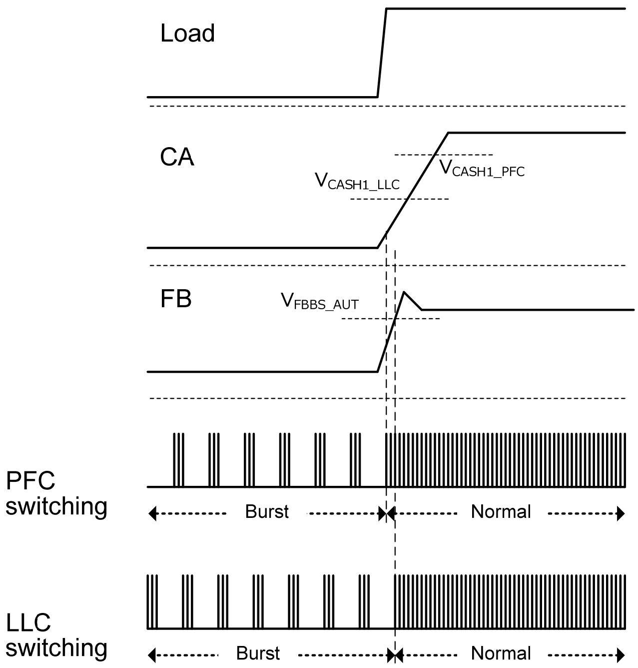


Fig. 19 Operating switch sequence by FB pin voltage

(6-3-3) Standby operation by external signal

Fig. 20 shows the switch sequence of standby operation by external signal.

[Switch from normal mode to low standby mode]

If the switch device between STB pin and GND is turned off, STB pin voltage rises according to the resistor connected to STB and STB pin source current. When STB pin voltage rises above V_{THSTBH}, the IC switches from normal to low standby mode with 108ms delay.

[Switch from low standby mode to normal mode]

If the switch device between STB pin and GND is turned on, STB pin voltage drops to 0V. When STB pin voltage drops below V_{THSTBL}, the IC switches from low standby mode to normal mode.

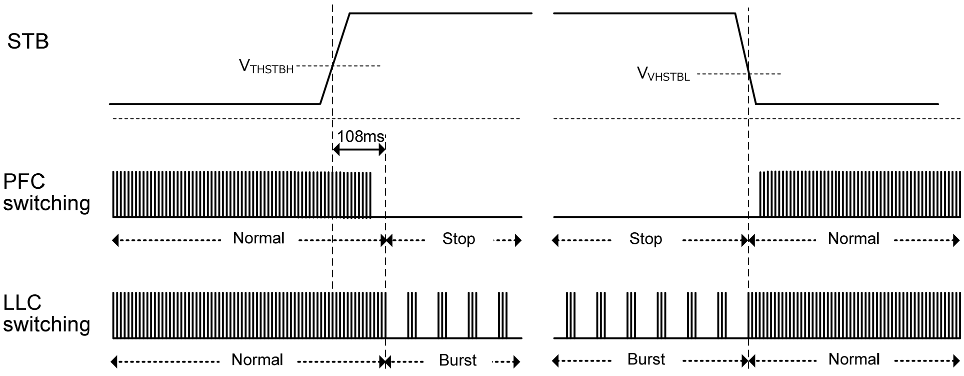


Fig. 20 Operating mode switch sequence (Standby by external signal)

(7)Capacitive mode prevention function

In the current resonance circuit, if the currents I_{D1} and I_{D2} becomes negative and then the MOSFET on the opposite side is turned on, shoot through occurs and shot circuit current may flows through the MOSFETs on the high and low sides. In the worst case, they may be destroyed.

Usually the minimum frequency is restricted to prevent shoot through. However, this method is not good enough against input voltage and load change and also restricts setting of the operating point.

In this IC, the resonant current I_{cr} is always monitored, MOFET is turned off before the currents I_{D1} and I_{D2} of Q_1 and Q_2 become negative, and the opposing MOSFET is turned on. Therefore, operation is continued without any shoot through. The resonant current is shunted by the shunt capacitor C_{rd}, converted into the voltage V_{IS} by the resistor R_{IS} and detected by the IS pin as shown in Fig. 21. When you use this IC, connect the primary winding of transformer and resonant capacitor in parallel with the low-side Q_1.

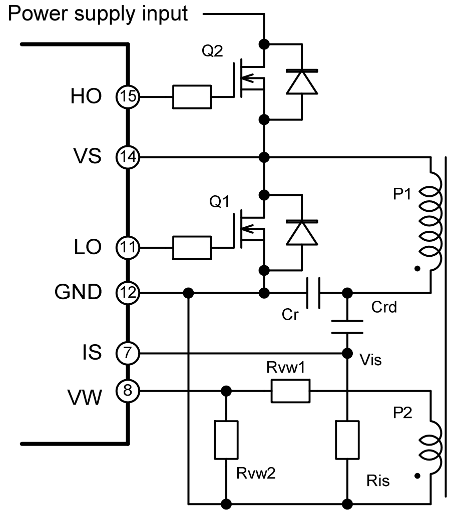


Fig. 21 Capacitive mode prevention function circuit diagram

The capacitive mode prevention function has two functions, namely the forced turn-off function and the dead time automatic adjusting function.

(7-1) Forced turn-off function

During normal operation, the MOSFET is turned off according to oscillator. However, the IC turns off the MOSFET forcibly in the following two cases because there is a possibility that shoot through may occur.

[Conditions to operate the forced turn off]

1. When the VW pin voltage rises over the forced turn-off threshold V_{THVWP} (threshold voltage is switched between normal operation mode V_{THVWPN} and low standby mode V_{THVWPS}) and the voltage of the IS pin, which detects the resonance current I_{cr}, exceeds V_{THISM}.
2. When the VW pin voltage drops below the forces turn-off threshold V_{THVWM} (threshold voltage is switched between normal operation mode V_{THVWMN} and low standby mode VT_{HVWMS}) and the voltage of the IS pin, falls below V_{THISP}.

Fig. 22 shows the relation among the VW auxiliary winding, the resonance current I_{cr} and the forced turn-off detecting point.

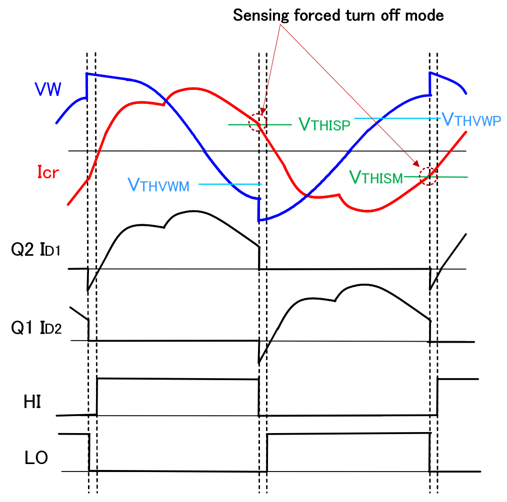


Fig. 22 Forced turn off function waveform

(7-2) Self-adjusting dead time function

During startup or burst operation, the through current or the hard switching are more likely to occur at the switching frequency near the maximum frequency. This IC is equipped with the self-adjusting dead time function to prevent such problems.

By detecting the gradient dV/dt of the VW auxiliary winding voltage, this function detects the VS pin voltage change and turns on the high-side or low-side MOSFET. MOSFET is turned off according to the off signal of the oscillator.

The automatic adjustment range of dead time is set within the IC, and the minimum dead time is 430ns.

In transformer design, the polarity of the VW auxiliary winding must be reversed with respect to the primary winding P_1 as shown in Fig. 23. The VW auxiliary winding can also be used as VCC auxiliary winding for supplying power to the VCC pin.

The principle of the dead time automatic adjusting function by the VW auxiliary winding P_{VW} is as follows.
When the VS voltage is inverted, the formula (9-1) can be obtained.

$$N \cdot V_{vw} = V_s + V_{cr} - V_i \qquad (9\text{-}1)$$

When the formula (9-1) is differentiated, the formulas (9-2) and (9-3) can be obtained.

$$\frac{dV_{vw}}{dt} = \frac{1}{N}\left(\frac{dV_s}{dt} + \frac{dV_{cr}}{dt}\right) \qquad (9\text{-}2)$$

$$= \frac{1}{N}\left(\frac{I_{cr}}{C_{vs}} + \frac{I_{cr}}{C_r}\right) \qquad (9\text{-}3)$$

Since usually $C_r >> C_{VS}$ is valid, Formula (9-3) can be approximated.

$$\frac{dV_{vw}}{dt} \approx \frac{1}{N}\frac{dV_s}{dt} \qquad (9\text{-}4)$$

Accordingly, with Formula (9-4), the VS voltage change can be detected by the VW auxiliary winding voltage change (dV_{VW}/dt).

When the switching frequency is high, the VW voltage changes only very slightly during on period because the resonant current is small as shown in Fig. 24. Therefore, the waveform of VW voltage is almost the same as that of the VS voltage.

Accordingly, after a constant delay (t_{DVWONP} or t_{DVWONM}) because the VS voltage inversion is detected by VW voltage, the turn-on signal is sent.

When the switching frequency is low, dV/dt of the VW voltage is detected during on period and the turn-on signal for the next cycle can be obtained because the resonance current is large as shown in Fig. 25. In this case, the dead time is the minimum dead time t_D.

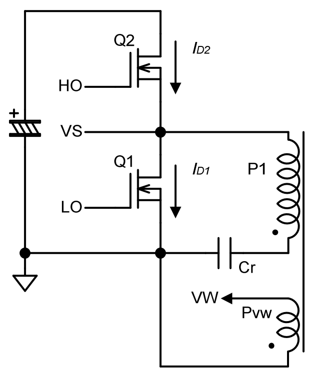


Fig. 23 Outline of primary side circuit

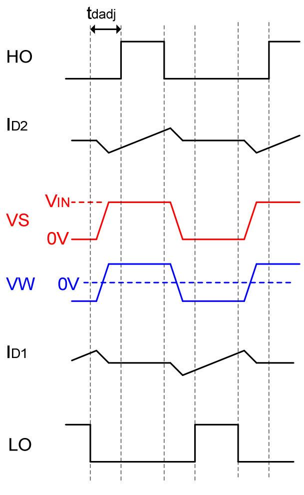


Fig. 24 Waveforms at higher frequency

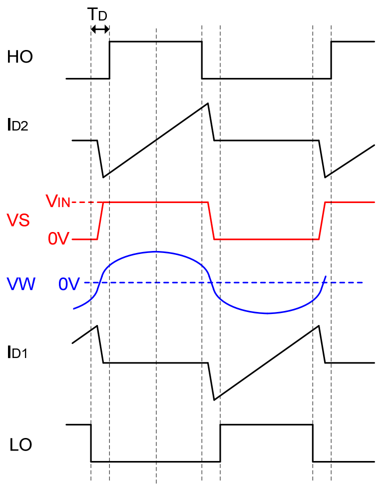


Fig. 25 Waveforms at lower frequency

(8) Dynamic Self Supply (DSS) function

By the DSS function, if the VCC pin voltage decreases, the startup circuit is set to ON/OFF, thereby maintaining the VCC pin voltage within a certain range. In this IC, when VCC pin voltage decreases below start-up circuit start voltage of 10V, start-up circuit operates and VCC pin voltage rises. When VCC pin voltage reaches to start-up circuit stop voltage of 11V, start up circuit is stopped. Regardless of state such as protection period or stop with latch protection, DSS function operates when VCC pin voltage decreases below start-up circuit start voltage. However, since the IC cannot operate only with the current supplied from the startup circuit in normal switching state, VCC voltage from the auxiliary winding must be supplied.

(9)Protection by external signal

The MODE pin also has the protection function to stop switching by external signal. If MODE pin is pulled down below 0.35V of threshold voltage for external fault stop for 304us of delay time, IC stops switching. In the switching stop period, VCC pin voltage is maintained within the range of 10V to 11V. During the period when MODE pin is kept below the threshold voltage (0.35V typ.), switching is stopped. Switching is resumed when MODE pin voltage rises over the threshold voltage (0.35 V typ.).

(10) Overcurrent protection function

As shown in Fig. 21, the resonant current is detected by the IS pin through the shunt capacitor and current sense resistor.

If the IS pin voltage exceeds the over current threshold voltage, the MOSFET is turned off at each oscillation cycle.

In addition, if the IS pin voltage over the over current threshold for the delay time of over current, switching is stopped forcibly. If IS pin voltage drop below threshold for the over current detection reset time of 76us or longer, the overcurrent detection is reset. The delay time of over current can be set within the range from 1 to 19ms by MODE pin oscillator and counter which operates based on the MODE pin capacitor charge/discharge. When 810ms elapses after the switching is stopped, IC starts switching. If over current condition is detected again, switching is stops. (auto recovery type)

The over current threshold is different in “low standby mode or OLP of FB pin” and “normal mode”. In case of “low standby mode or OLP of FB pin” it is ±2.6V, and in case of “normal mode” it is ±4.0V.

(11) Overvoltage protection (VCC pin)

If the secondary output becomes overvoltage, the voltage of the auxiliary winding also increases. The VCC pin has a function of detecting the voltage of this auxiliary winding, and if the VCC pin voltage exceeds the over voltage threshold of 30.6V for 304us, switching stops. In the switching stop period, VCC pin voltage is maintained by startup circuit. When 810ms elapses after the switching is stopped, switching is resumed and if overvoltage condition is continued, switching is stopped again. (auto recovery type)

(12) Under voltage lockout function

To prevent circuit malfunction due to decreased Vcc, an under voltage lockout circuit is integrated. When the VCC pin voltage increases from 0V, operation is started when the voltage reaches start operation voltage of 14V. When the VCC voltage decreases, operation is stopped when the voltage reaches shutdown voltage of 9V.

In addition, the voltage between the VB pin and the VS pin, namely high-side Vcc, is also detected, and operation is started when the high side Vcc increases to the V_{BS} switching start voltage of 8.8V, and the operation is stopped when it decreases to the V_{BS} switching stop voltage of 7.5V.

(13) Internal thermal shutdown protection function

If the IC temperature increases to 140˚C, switching is stopped. When the temperature decreases to 120˚C, the switching is resumed.

(14) Discharge function of the input filter X-capacitor at AC power interruption

By connecting the VH pin to the X-capacitor of the AC line filter through full-wave rectification, the X-capacitor can be discharged when AC input is powered off. This function eliminates discharge resistor for X-capacitor, thereby decreasing standby power.

The recommended capacitance of connectable X-capacitor is 2μF or lower.

(Requirement in UL60950 regarding electric shock: The voltage value of the power supply input part shall be attenuated to 37% or lower of the peak value within 1s after the AC input voltage is powered off.)

(15) Overload protection

(15-1) In case of standby operation by external signal

If the state where the CA pin voltage remains at the over load detection CA voltage or higher, or the FB pin voltage remains at the over load detection FB voltage or higher, is continued for the delay time of over load (CA pin OLP : 38ms, FB pin OLP : 76.8ms) , switching is stopped forcibly. When switching is stopped, supply of current from the auxiliary winding is stopped, and the VCC pin voltage decreases to 10V, the startup circuit is operated, and the VCC voltage is maintained within a range from 10V to 11V. When 810ms elapses after the switching is stopped, switching is resumed. If overload state is continuing at that time, switching is stopped again. (auto recovery type)

Note that overload protection function by FB pin voltage is invalidated at the time of soft start.

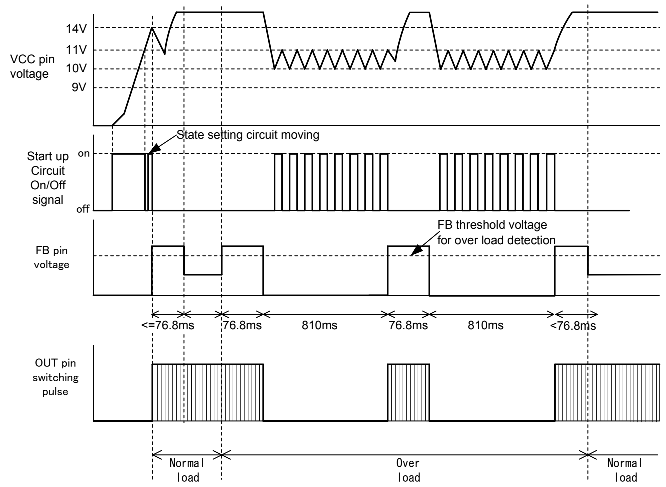


Fig. 26-1 Overload detection operation by FB pin

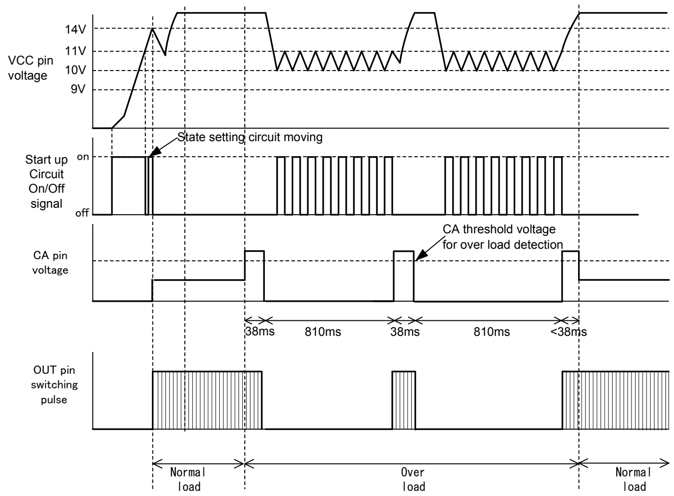


Fig. 26-2 Overload detection operation by CA pin

Fig. 26 Overload protection with standby by external signal

(15-2) In case of auto standby operation

In case of auto standby operation, restart sequence is different after the switching stop period of 810ms.
When 810ms elapses after the switching is stopped, start up circuit operates and charges Vcc. When Vcc rises to 14V, PFC starts pre-switching similar to start up sequence, i.e. PFC start switching prior to LLC in order to raise PFC output voltage enough. (See page 41 for details.) The period of PFC pre-switching is 320ms. Therefore, LLC starts switching after 1130ms elapses.

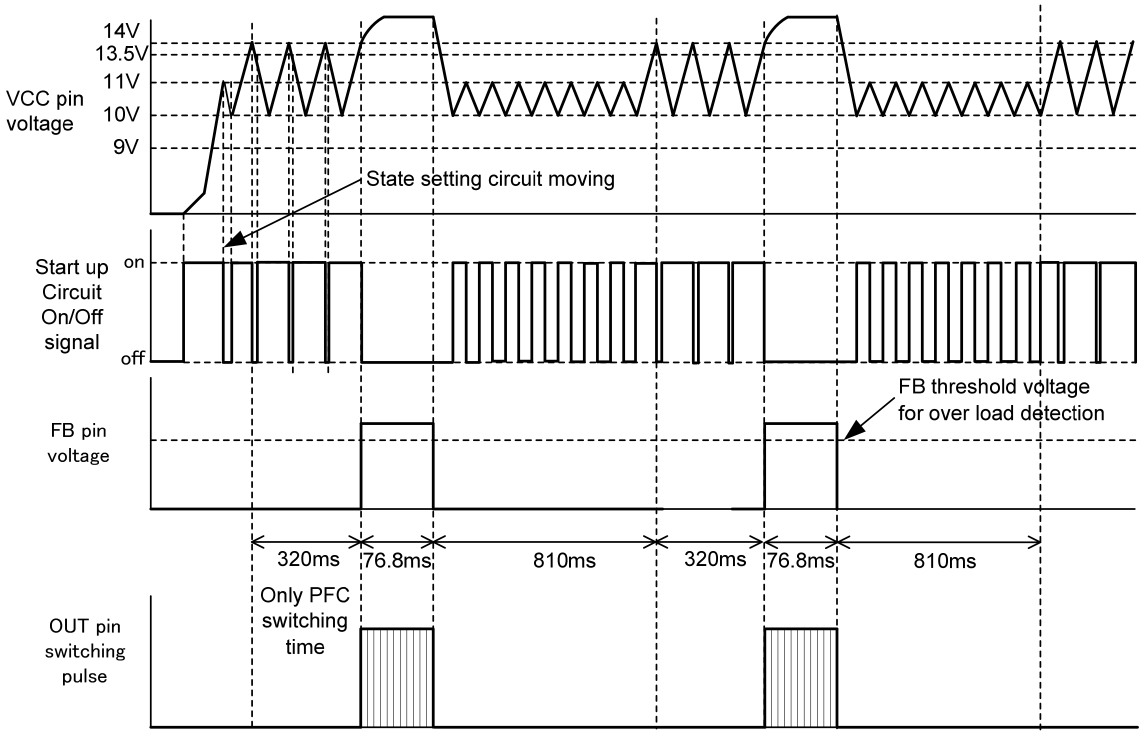


Fig. 27 Overload protection with auto standby

(16) VCC voltage drop protection function

When VCC voltage falls to 9V or less under the condition of output short etc. IC stops switching and VCC voltage is maintained by start up circuit. When 810ms elapses after the switching is stopped, IC starts switching again.(auto recovery type)

(17) Level-fixed VH pin brown-in/out function

The brown out function and brown in function are integrated. The brown out function stops switching when the AC line voltage decreases and the brown-in function does not allow switching until the AC line voltage increases to a specified voltage.

The VH pin voltage is directly monitored by this function. If VH pin voltage decreases below the brown out threshold of 61Vdc, switching does not stop immediately but stops with delay time of 47ms. If the VH pin voltage exceeds the brown-in threshold of 92Vdc, switching starts with delay time of 160us.

While brown-out function operates, the VCC voltage is maintained the range from 10V to 11V by of the startup circuit.

(18) VB pin brown out function

While VH pin brown out detection is active, such as just after input voltage turned off, if VB pin voltage drops, this function stops switching.

When input voltage is turned off and VH pin voltage drops below 61Vdc, this IC detects brown out condition. However, brown out function does not stops switching during the delay time of 47ms. In that time, if input voltage of LLC main drops largely, amplitude of VW pin signal for capacitive mode prevention function becomes small and forced turn off function may not operate correctly, then capacitive mode operation may occur.

To prevent such operation, when VH pin brown out detection is active and VB pin voltage drops below 52V, this function stops switching with delay time of 608us. VB pin voltage is monitored during the on state of high side driver.

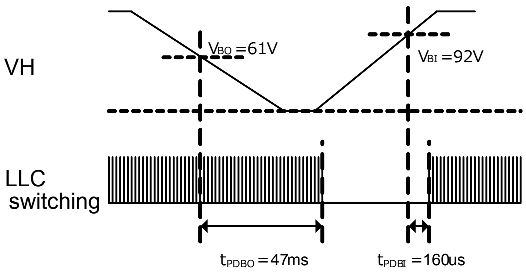


Fig. 28 VH pin brown in/out waveform

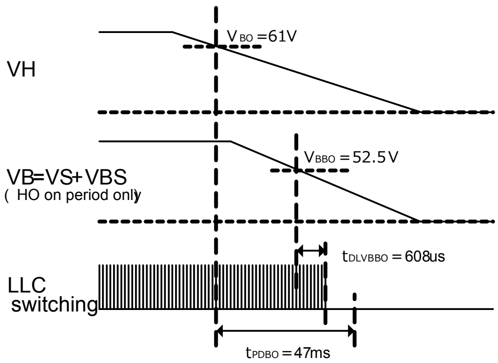


Fig. 29 VB pin brown out waveform

(19) Start up sequence (in case of standby operation by external signal)

Fig. 30 shows the timing chart at start up. Period of ① to ④ in the chart are described below.

① The AC input is turned on and start up circuit charges VCC pin voltage.

② When VCC pin voltage reaches start-up circuit stop voltage V_{STOFF} of 11V, the IC starts state setting (48ms max.). During state setting, VCC pin voltage is maintained in the range of 10V and 11V by start up circuit.

③ After state setting, start up circuit supplies current to VCC pin again and increases VCC pin voltage to start operation voltage of 14V.

④ When VCC pin voltage reaches to start operation voltage, IC starts switching operation and auxiliary winding voltage of transformer increases. Then, VCC pin voltage is supplied from auxiliary winding and IC starts normal operation.

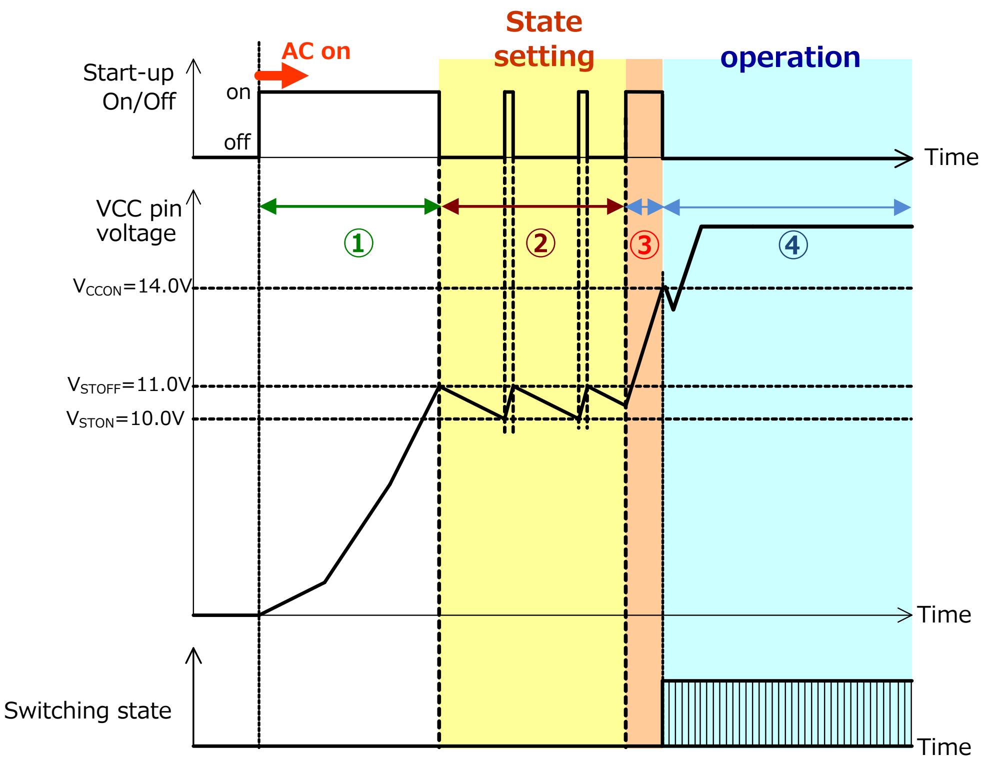


Fig. 30 Start up sequence

(20) Communication with FA1A60N

This IC has a communication function with CRM PFC IC "FA1A60N". The communication signal is sent from STB pin of FA6B20N to RT pin of FA1A60N. PFC operation, such as continuous, burst or stop, is controlled by the signal. (in auto standby operation only)

The merits to control PFC operation by LLC are listed below.

1. As for CRM PFC, inductor current becomes small and switching frequency becomes high at light load. Thus, switching loss becomes large and efficiency goes down. With communication function, input power is detected and PFC operation mode is switched from continuous to burst mode. As the result, efficiency at light load is improved.
2. LLC part can be started after PFC output voltage rises enough because LLC IC controls PFC operation. It helps to start up PSU with full load.

(20-1) Cooperation between FA6B20N and FA1A60N

Fig. 31 shows the circuit diagram of communication between FA6B20N and FA1A60N. FA6B20N detects input power and switches PFC to normal mode or burst mode. FA6B20N transmit the signal from STB pin and FA1A60N receives it at RT pin. As for signal transmission wiring, a buffer circuit for the signal should be inserted close to RT pin of FA1A60N. The communication signals are 5 types as listed in table 4. Details of the signal are described in page 45.

Fig. 32 shows the circuit diagram in case of using the communication between FA1A60N and FA6B20N. In addition to communication circuit, VCC pins of FA1A60N and FA6B20N are connected directly for startup with full load.

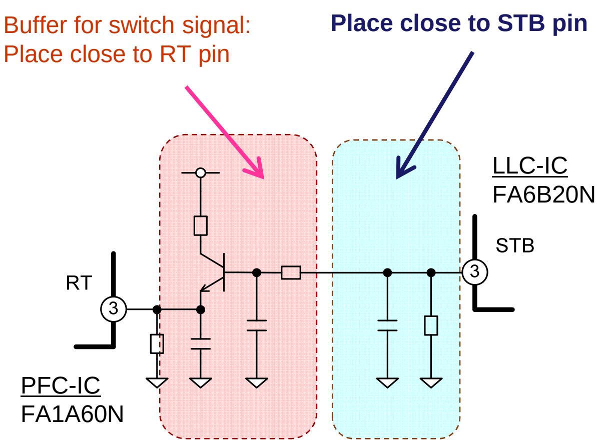


Fig. 31 Pin connection for communication function

Table 4: Communication signal between PFC and LLC

Operating mode	Standby pin output voltage	Signal width	Number of signal
Normal to burst (Vin=100V line)	3V	6ms	2 pulses
Normal to burst (Vin=200V line)	3V	6ms	1 pulse
Burst to normal (Vin=100V line)	3V	0.5ms	2 pulses
Burst to normal (Vin=200V line)	3V	0.5ms	1 pulse
PFC stop	5V	0.25ms	Continuous

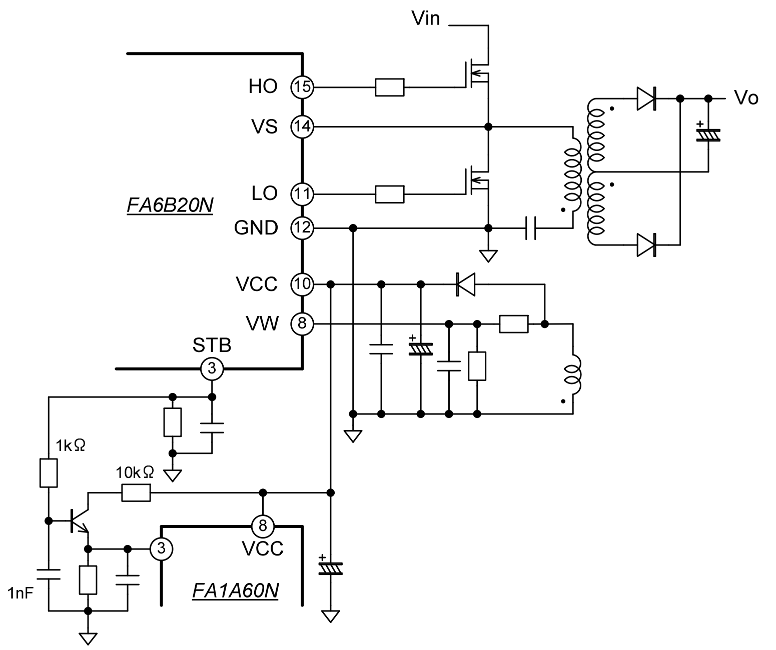


Fig. 32 Circuit block diagram for communication between PFC and LLC

(20-2) Start up sequence (in case of auto standby operation)

Fig. 33 shows the timing chart at start up in case of cooperate with FA1A60N.

① The AC input is turned on and start up circuit charges VCC pin voltage.

② When VCC pin voltage reaches start-up circuit stop voltage V_{STOFF} of 11V, the IC starts state setting (48ms max.).

③ After state setting, the IC starts PFC start up period (380ms typ.).

1. VCC pin voltage rises by start up circuit.
2. When VCC pin voltage reaches LLC start operation voltage V_{CCON} of 14V, PFC starts switching.
3. When VCC pin voltage drops to Start-up circuit start voltage V_{STON} of 10V, PFC stops switching.
4. VCC pin voltage rises again by start up circuit. When VCC pin voltage reaches LLC start operation voltage V_{CCON} of 14V, PFC starts switching again. LLC part keeps stop state.
5. Operation of state 3 to 4 are repeated during PFC start up period.
6. After the PFC start up period, PFC stops switching.

④LLC and PFC operation period starts.

1. VCC pin voltage rises by start up circuit.
2. When VCC pin voltage reaches LLC start operation voltage V_{CCON} of 14V, both PFC and LLC starts switching.
3. VCC pin voltage is supplied from auxiliary winding and IC starts normal operation.

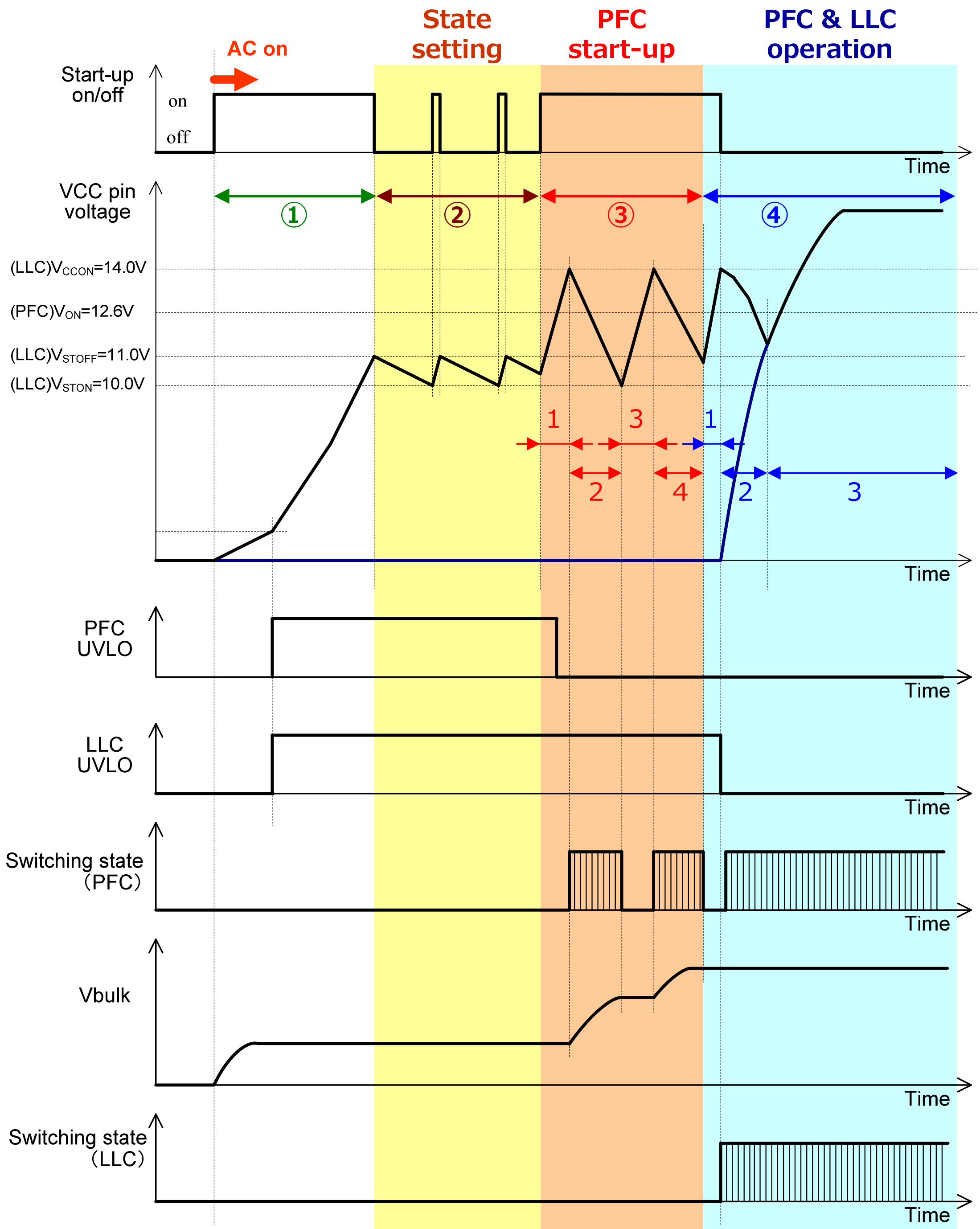


Fig. 33 Start up sequence

9. How to use each pin and advice for designing

(The values that appear in the following description are typical values, unless otherwise specified.)

No.1 : VH pin

(1)Function

(i) Supplies the startup current from the VH pin to the VCC pin.
(ii) Discharges the X-capacitor of the AC line filter when AC input is powered off.
(iii) Fixed-level brown-in/out function is provided.

(2) How to use

(i) Supplying startup current

✓Connection method

Connect to AC line voltage via a startup resistor and diodes as shown in Fig. 34. Fig. 34 shows the method of inputting full-wave rectified waveform of the AC line voltage into the VH pin. If X-capacitor discharge function should be used, connect VH pin as Fig. 34.

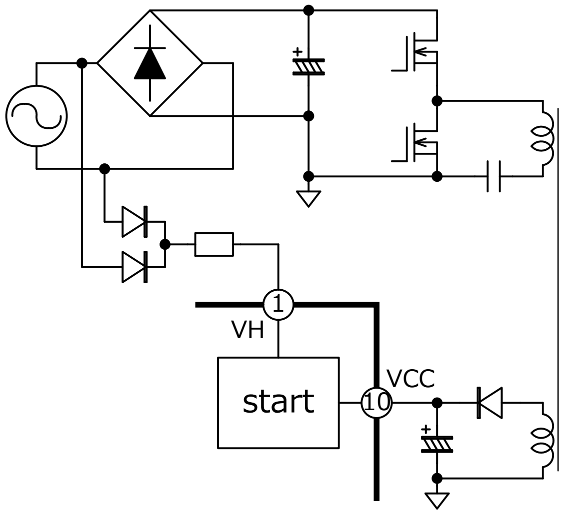


Fig. 34 VH pin circuit

✓Unusable connection method

If the VH pin is connected to DC voltage which means rectified and smoothed AC line voltage as shown in Fig. 35, the discharging function of the X-capacitor may malfunction, thereby causing heating and damage. Never adopt this connection method shown in Fig. 35.

If the VH pin is connected not to full wave rectified waveform but to half wave rectification waveform, X-capacitor discharge function does not operate fully and IC may not start up with recommended VH pin resistor (40kΩmax.). Thus, half waveform rectification is not recommended.

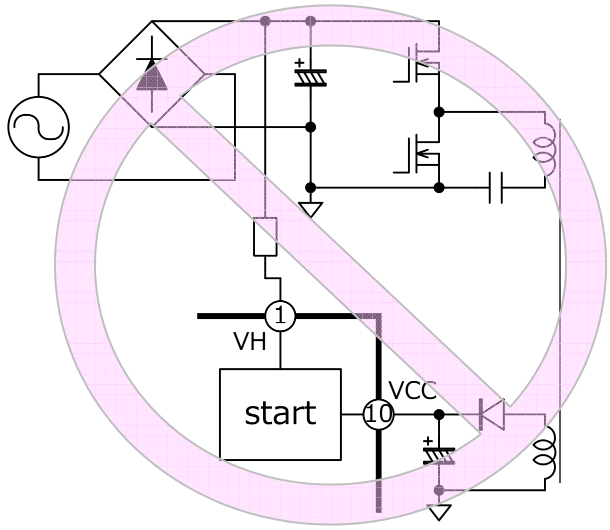


Fig. 35 Connection that should not be adopted

✓Operation

When AC power is turned on, the capacitor connected to the VCC pin is charged by the current supplied from the startup circuit to the VCC pin via the VH pin, and the VCC voltage increases. When Vcc exceeds the start-up circuit stop voltage of 11V, the internal supply is started to operate the IC.

If Vcc is supplied from the auxiliary winding, the startup circuit is remains in off state. Since it is not possible to keep operating the IC using the current supplied from the startup circuit without using the auxiliary winding in normal operation state, Vcc voltage should be supplied from the auxiliary winding.

(ii)AC line filter X-capacitor discharge function

✓**Connection method**

This function operates with the connection method shown in Fig. 34 only.

✓**Operation**

The AC input voltage is monitored by the VH pin, and when the AC input is cut off, the discharging function of the X capacitor will operate after 56ms of the delay time of AC cutting detection.

The function discharges the X-capacitor with average current of 2mA repeating ON and OFF state; ON state is for 1.5ms and OFF state is for 0.5ms.

When the AC input is resumed, the X-capacitor discharging function stops.

(iii) Brown-in and brown-out functions

✓ **Connection method**

This function operates with the connection method shown in Fig. 34.

✓**Operation**

When the VH pin voltage increases to the VH pin brown-in voltage of 92Vdc or higher, and the VH pin brown-in detection delay time of 160 us elapses in that state, switching is started.

Also, when the AC input voltage decreases to below the VH pin brown-out voltage of 61Vdc, and the VH pin brown-out detection delay time of 47ms elapses in that state, output switching stops.

While the switching is suspended by the brown-out function, the startup circuit is controlled as ON and OFF to maintain the VCC voltage is within the range from 10V to 11V. Switching operation is resumed when the VH pin voltage reaches the VH pin brown-in voltage.

(3)Advice on design

1. Startup resistor

To prevent damage to the IC due to surge voltage of the AC line, it is recommended to connect a VH pin resistor of 2kΩ to 40kΩ to the VH pin in series. Note, however, large resistance causes long startup time.

2. X-capacitor capacitance

To satisfy the requirements of UL60950 regarding electric shock, this IC integrates a discharge function for the voltage at the power input part to 37% or lower of the peak value within 1s after the AC input voltage is powered off.

The recommended capacitance of connectable X-capacitor is 2uF or lower.

3. VH pin capacitor

When a capacitor is connected between VH pin and GND to remove noise, 470pF or lower capacitor is recommended. If the capacitor is too large, the X-cap discharge function may malfunction.

No.2 : NC pin

This pin is not connected to the IC internally because it is located next to the high-voltage pin (VH).

No.3 : STB pin

(1) Function

(i) By mode selection function, switch method is selected between “auto standby operation” and “standby operation by external signal”. In addition, CA pin OLP threshold is selected.

(ii) In case of “standby operation by external signal”, STB pin is used as input pin of external signal for low standby mode.

(iii) In case of “auto standby operation”, STB pin outputs communication signal to control the operating mode of PFC IC “FA1A60N”.

- If “auto standby operation” is selected, STB pin outputs the operation mode signal. If “standby operation by external signal” is selected, STB pin operate as input pin to switch the operating mode.

(2) How to use

(i)Operating mode setting

✓**Connection method**

Connect a resistor and capacitor in parallel between STB pin and GND. Select the resistor based on the table 5. 1000pF is recommended for capacitor.

Table 5: Standby pin resistor and mode selection

Mode	STB pin	Switch method	CA pin OLP
A	33KΩ	Standby by external signal	1.5V
B	82KΩ	Auto standby	
C	300KΩ		3.0V

✓**Operation**

When the VCC pin voltage rises to 11V at start up, the mode selection source current of 36 uA is output from the MODE pin, and mode setting is made depending on the voltage generated resistor between the STB pin and the GND.

(ii) Selection between normal mode and low standby mode by external signal

✓**Connection method**

Connect a resistor, capacitor, and a switch element such as transistor or photo-coupler between the STB pin and the GND (See Fig. 36)

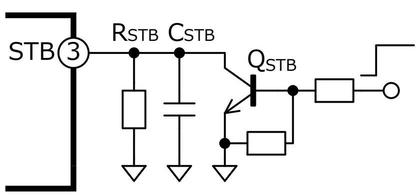


Fig. 36 Low standby mode switch circuit (Standby by external signal)

✓**Operation**

If “standby operation by external signal” is selected, STB pin operate as input pin. Operating mode can be switched between the normal mode, where IC operates with normal switching, and the low standby mode, where low standby power is achieved with burst operation, depending on the voltage of the STB pin.

By pulling down the STB pin voltage below the low standby mode detection voltage of 0.3V (V_{THSTBL}), IC operates in the normal mode.

To switch to the low standby mode, open the switch elements. Since 36uA current is output from the STB pin, STB pin voltage rises over the low standby mode detection voltage of 0.35V (V_{THSTBH}).

When the low standby mode detection delay time of 108ms elapses after the STB pin voltage reaches the threshold of 0.35V (V_{THSTBH}), burst operation is started.

(iii)Communication function with PFC IC FA1A60N

✓Connection method

This function operates with the connection shown in Fig. 37.

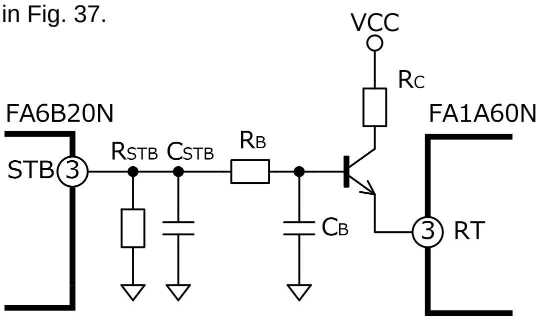


Fig. 37 Communication function circuit

As for signal transmission wiring, a buffer circuit for the signal should be inserted close to RT pin of FA1A60N in order to reduce noise influence. (example of the value: R_B=1KΩ、C_B=1nF、R_C=10KΩ)

Table 6. Communication signal

Operating mode	Standby pin output voltage	Signal width	Number of signal
Normal to burst (Vin=100V line)	3V	6ms	2 pulses
Normal to burst (Vin=200V line)	3V	6ms	1 pulse
Burst to normal (Vin=100V line)	3V	0.5ms	2 pulses
Burst to normal (Vin=200V line)	3V	0.5ms	1 pulse
PFC stop	5V	0.25ms	Continuous

✓Operation

In case of “Auto standby operation”, the IC detects input power with CA pin and switches the operation mode. When FA6B20N switches PFC operation mode, STB pin outputs communication signal.

Details of communication signal is listed in table 6. Each communication signal waveforms are shown in Fig. 38 to 42.

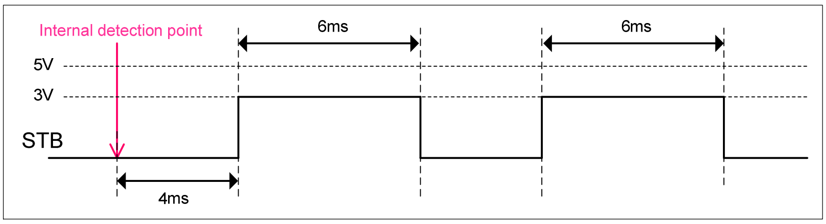


Fig. 38 Switch PFC form normal to burst (Vin=100V line)

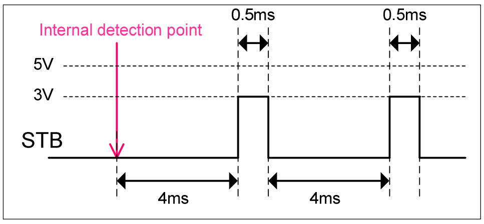


Fig. 39 Switch PFC from burst to normal (Vin=100V line)

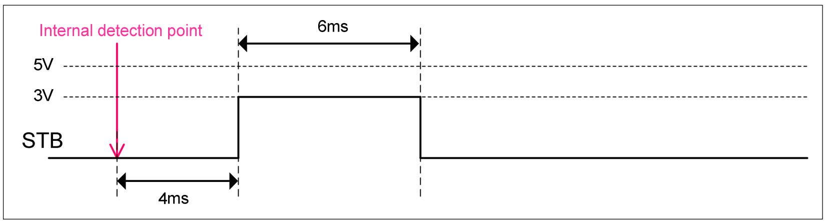


Fig. 40 Switch PFC form normal to burst (Vin=200V line)

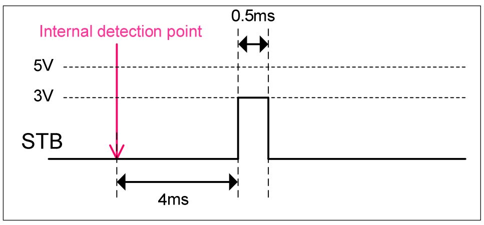


Fig. 41 Switch PFC from burst to normal (Vin=200V line)

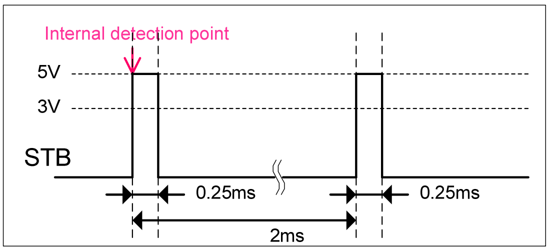


Fig. 42 PFC stop signal

No.4 : FB pin

(1) Function

(i) The feedback signal from the secondary side is input.
(ii) The overload state is detected.
(iii) Switching is stopped when the FB pin voltage is low.

(2)How to use

(i) Input of feedback signal

✓Connection method

Output of the photo-coupler is connected. In addition, a capacitor is connected in parallel to the photo coupler to suppress the noise.(See Fig. 43.)

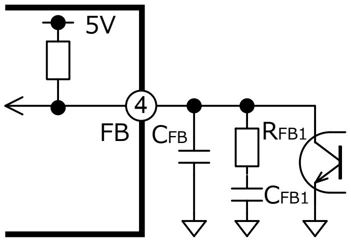


Fig. 43 FB pin circuit

✓Operation

FB pin is biased from internal bias voltage (5V) through a resistor. The FB pin voltage is decided by photo-coupler current and internal resistor.

The FB pin voltage is input into the oscillator, and the frequency is determined by the FB pin voltage.

When the FB pin voltage rises to 0.7V, switching is started at 270kHz and the frequency gradually decreases as FB pin voltage rises. When the voltage rises to 3V, the oscillation frequency decreases down to minimum of 25kHz.

(ii) Overload detection

✓Connection method

The same as the one described in (i) .

✓Operation

When overload state occurs and the output voltage of the power supply decreases to below the setting, the FB pin voltage increases. If the state, in which the FB pin voltage exceeds the over load detection FB voltage of 4.3V, continues for the delay time of over load of 76.8ms, switching stops.

In overload condition, operation is intermittent. When overload condition is eliminated, operation goes back to normal.

Note that the overload detection by the FB pin is canceled at the time of soft start.

(iii) Switching stop when FB pin voltage is low

✓Connection method

The same as the one described in (i)

✓Operation

When the FB pin voltage rises from near 0V at startup, etc., switching operation is stopped at less than 0.7V, and it is started when the voltage becomes 0.7V or over. After switching operation is started, it is stopped when the FB pin voltage becomes lower than 0.6V.

(3)Advice on design

1. Resistor and capacitor between FB and GND

Insert a filter, which consists of resistor and capacitor, between the FB pin and the GND pin to prevent malfunction caused by noise. (See Fig. 43.)

See the following for the guideline of constants of parts.

[External standby]
C_{FB1}=0.47uF, R_{FB1}=2.2kΩ, C_{FB2}=1nF
[Auto standby]
C_{FB1}=0.47uF, R_{FB1}=4.7kΩ, C_{FB2}=22nF, R_{FB2}=18kΩ

Make the wiring between the photo coupler and the FB pin/the GND as short as possible to avoid noise. Also do not place the wiring near the transformer.

2. Prevention of output voltage drop at standby

This IC uses FB burst control method so that large power can be output in low standby mode. However, as output power increases, bottom of output voltage goes down gradually because of response of FB pin. Therefore, it is recommended to apply FB pin response switch circuit between normal mode and low standby mode.

Recommended circuit for auto standby operation is shown in Fig. 44 and for standby by external signal is shown in Fig. 45.

Connect MOSFET gate through resistor divider to PFC Vcc for external standby or CS pin for auto standby. (Fig. 45)

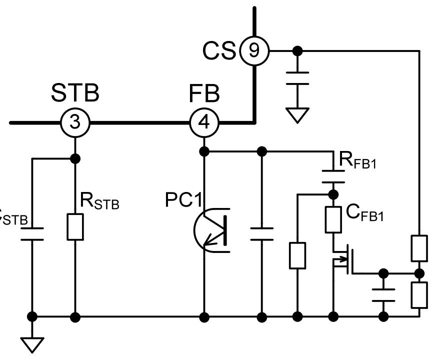


Fig. 44 FB pin response switch circuit (Auto standby)

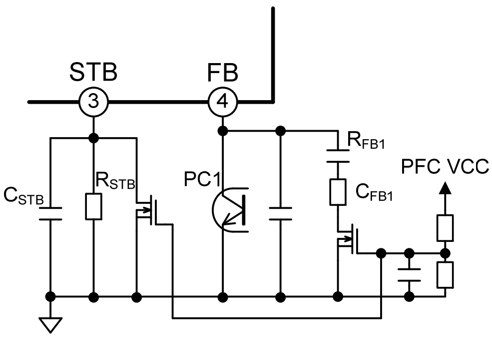


Fig. 45 FB pin response switch circuit (Standby by external signal)

No.5: MODE pin

(1)Function

(i) With MODE selection function of MODE pin, functions listed below are selectable. (Only for auto standby operation)

- Switch level of LLC and PFC between low standby mode and normal mode
- VW pin threshold for forced turn off while the delay period to release CS clamp

(ii) Set the delay time for overcurrent protection (IS pin).

(iii) Protection operates by an external signal.

(2)How to use

(i) Operating mode setting

✓Connection method

Connect a resistor and a capacitor in parallel between the MODE pin and the GND.

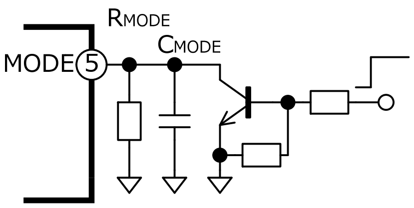


Fig. 45 MODE pin circuit

✓Operation

At startup, input voltage is applied and VCC pin voltage rises to 11V, then mode selection source current of constant current is output from the MODE pin. Operating mode is selected depending on the voltage generated resistor between the MODE pin and the GND. See Table 3 on page 30 for the operation mode settable by resistors. Fig. 46 shows the waveform of each mode selection.

MODE "A" to "D"

MODE pin voltage is determined with the constant current 40uA from the MODE pin and the resistor between MODE pin and GND. The mode selection time in this period is 15ms. If the resistance value is 56kΩ(MODE "D") or lower, the mode selection is completed in this period. If the resistance value of the MODE pin is higher than 82kΩ (MODE "E"), the MODE pin voltage reaches V_{MODE12} (2.65V typ.) and the MODE pin voltage is discharged rapidly.

MODEs "E" to "H"

After the MODE pin has been discharged rapidly, the MODE pin voltage rises again with the constant current of 10uA. Then, the MODE is determined based on the resistance value of the resistor connected. The mode selection time in this period is 30ms. If the resistance value of the MODE pin is 270kΩ(MODE "H") or lower, the mode selection is completed in this period. If the resistance value of the MODE pin is higher than 270kΩ (MODE "H"), the MODE pin voltage reaches V_{MODE23} (3.15Vtyp), and the MODE pin voltage is discharged rapidly again.

MODE "I" and detection of open of the MODE pin

After the rapid discharging of the MODE pin, the MODE pin voltage rises again with constant current of 3uA, and the MODE is determined based on the resistance value of the resistor connected. The mode selection time in this period is 40ms. Note that if the resistor is in open state at the time of operating mode setting, the MODE pin voltage increases above the mode selection resistor open detection voltage of 1.4V. Consequently, latch off occurs.

The operating mode setting time is about 40ms from 10ms. After the setting time elapses, the VCC pin voltage increases again, and when it reaches the start operation voltage of 14V, switching is started. During normal operation, except when operating mode is being set, the MODE pin is kept clamped at 0.53V.

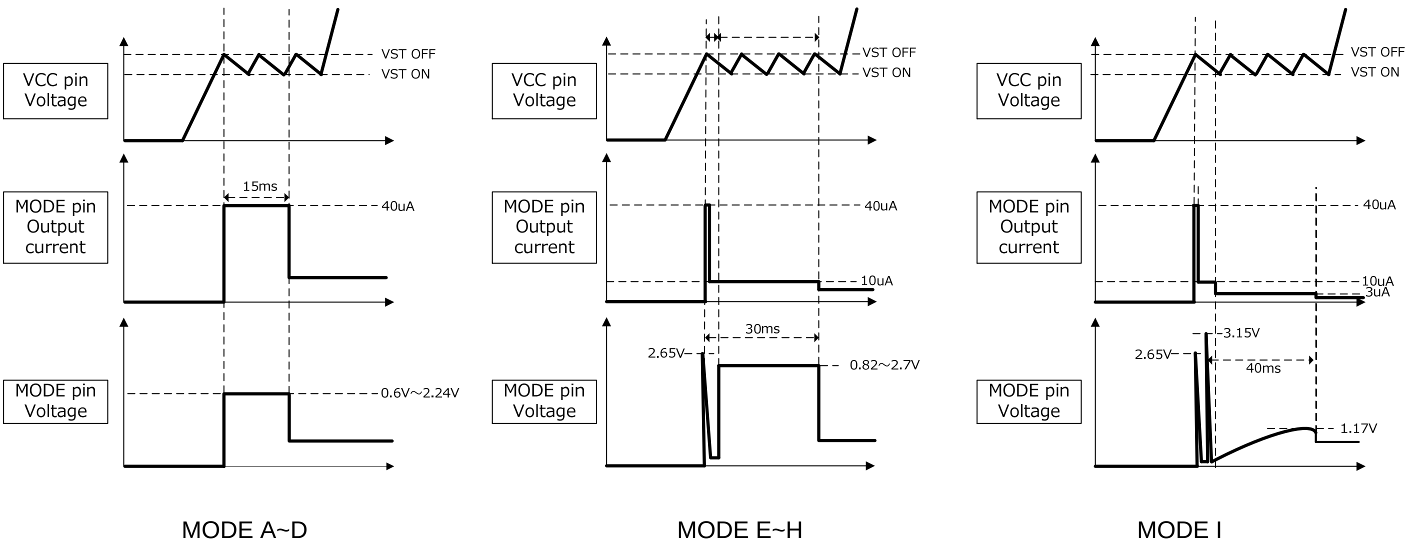


Fig. 46 MODE pin mode selection waveforms

(ii) Setting the delay time for OCP (IS pin)

✓**Connection method**

The same as the one described in (i) .

✓**Operation**

The MODE pin voltage is clamped at 0.53V during normal operation. If the IS pin detects state of overcurrent, constant current of 65uA is output from the MODE pin to charge the capacitor. When the MODE pin voltage reaches 1.4V, the output of the constant current is stopped, and the electric charge of the capacitor is discharged by the discharge current 65uA. When the MODE pin voltage decreases to 0.65V, the charge current is output again. The MODE pin repeats this oscillation state, and when the number of times of oscillation reaches 32, switching is stopped. (See Fig. 47.) The delay time is settable in a range approximately from 1ms to 19ms.

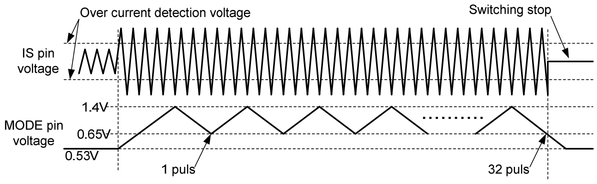


Fig. 47 Overcurrent delay time counting operation

(iii)Protection by external signal

✓**Connection method**

Connect a switch element as Fig. 45 or Fig.48.

✓**Operation**

The MODE pin is kept at 0.53V during normal operation. At this time, source current of 110uA is being output from the MODE pin. If the MODE pin voltage is pulled down by the external switch below protection threshold of 0.35V for 304us or longer, switching is stopped. After the switching is stopped, the VCC pin voltage is maintained by the startup circuit. During the period when MODE pin is kept below the threshold voltage (0.35V typ.), switching is stopped. Switching is resumed when MODE pin voltage rises over the threshold voltage (0.35 V typ.).

(3)Advice on design

1. Overvoltage protection on the secondary side using the MODE pin

Overvoltage protection on the secondary side using the MODE pin can be configured. Fig. 48 shows the example.

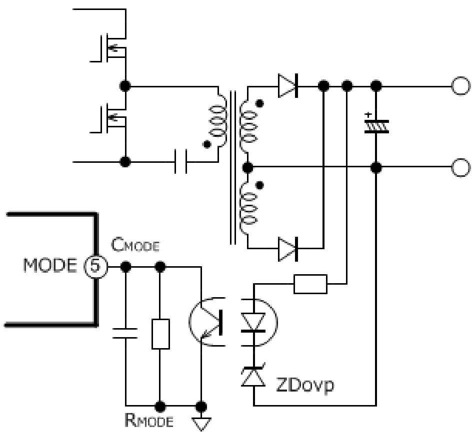


Fig. 48 Secondary side OVP using MODE pin

2. Setting the delay time for OCP (IS pin)

Fig. 49 shows the guideline for setting overcurrent delay time based on the CR of the MODE pin.

Since the MODE pin also has the function of setting the operating mode by resistance value, to set the delay time for overcurrent T_{OCPDLY}, it is necessary to determine the capacitor C_{MODE}, depending on the R_{MODE}.

(Recommended operating condition : 1nF - 22nF)

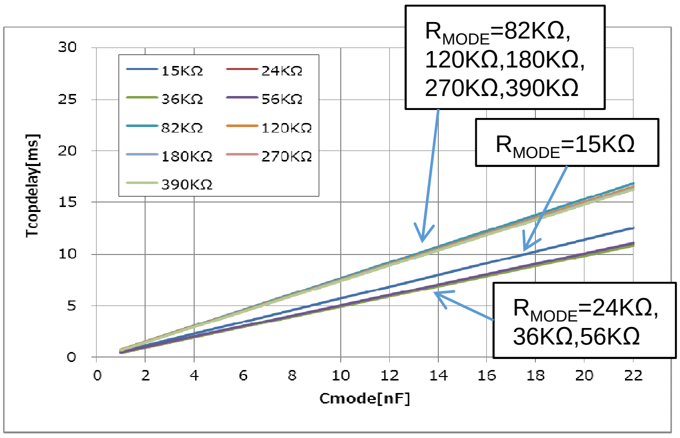


Fig. 49 Guideline for setting delay time for OCP

<u>**No.6 : CA pin**</u>

(1) Function

(i) Outputs voltage according to the input power of LLC.
(ii) Detects overload and operates protection function
(iii) Switches to low standby mode automatically depending on the voltage.

(2) How to use

(i) Outputs voltage according to the input power of LLC

✓**Connection method**

Connect a capacitor between the CA pin and the GND. If adjustment of mode switch level is required, also connect a resistor .

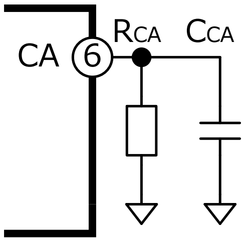


Fig. 50 CA pin circuit

✓**Operation**

IC monitors the primary input power by detecting input current of LLC at IS pin and smoothing the current signal at CA pin.

Conversion gain from IS pin to CA pin is switched at two point as Fig. 51 in order to widen operating voltage range of CA pin. When load is increased and CA pin voltage increases to 1.45V, gain is switched and CA pin voltage drops to 0.725V. When load is decreased and CA pin voltage decreases to 0.6V, gain is switched and CA pin voltage rises to 1.2V.

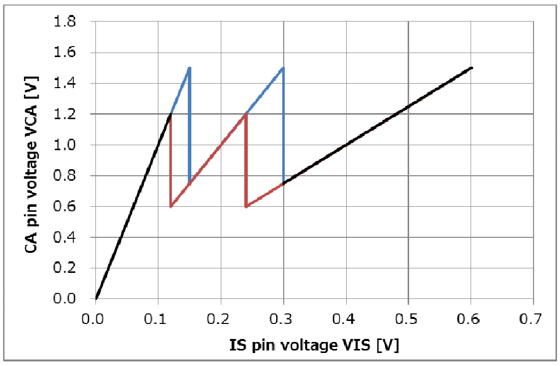


Fig. 51 CA pin voltage vs. IS pin voltage

(ii) Detecting overload and operates protection function

✓Connection method

The same as the method described (i) .

✓Operation

If the CA pin voltage reaches preset voltage (1.5V or 3.0V) with STB pin mode selection, overload is judged to be occurring, and after the overload protection delay time of 38ms has elapsed, switching is stopped. Switching is restarted after the interruption of 810ms.

(iii) Switch function between low standby and normal mode automatically according to the voltage

✓Connection method

The same as the method described (i) .

✓Operation

When the output power decreases, CA pin voltage also decreases. If CA pin voltage drops to the preset voltage with MODE pin resistor, the IC switches to low standby mode automatically. When the output power increases and CA pin voltage increases to preset voltage, the IC also switches from low standby mode to normal mode automatically.

(3)Advice on design

Select a capacitor from 0.1 to 0.47μF for CA pin.

The auto standby operation and overload protection is based on the CA pin voltage. The CA pin voltage is decided according to the IS pin voltage. Therefore, IS pin resistor R_{IS} affects the threshold power for auto standby and overload protection. In addition, R_{IS} is used for overcurrent protection.

When adjust each components, select R_{IS} and R_{CA} which satisfies above conditions.

Input power detection function does not monitor input voltage because it is designed on the premise that PFC is used. If PFC output voltage is changed, the CA pin voltage also changes even with the same output power. Please evaluate enough when PFC output voltage is changed.

No.7 : IS pin

(1)Function

(i) This pin detects the resonance current value and compare with the threshold voltage, which decides the forced turnoff for the preventing capacitive mode function.

(ii) This pin detects the resonance current value for each switching cycle and forcibly turns off switching in case of overcurrent.

(2)How to use

(i)Detection of the IS pin voltage for the preventing capacitive mode function

✓Connection method

Because the loss increases when the current flowing into the resonance capacitor is monitored directly, a shunt capacitor is connected and the current is converted into the voltage by the resistor as shown in Fig. 52. Then, it is input into the IS pin and the resonance current value is detected. To suppress the noise, connect a capacitor (C_{IS}=100pF recommended) between the IS pin and the GND. In addition, connect a CR filter depending on noise level. (See Fig. 52.) Recommended resistor R_1 of the CR filter is 100Ω.

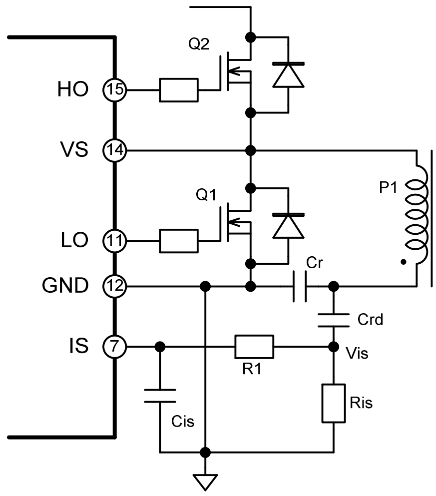


Fig. 52 IS pin circuit

✓Operation

See page 34 for details of the preventing capacitive mode function.

(ii) Overcurrent protection

✓**Connection method**

The same as the one described in (i).

✓**Operation**

If the IS pin voltage exceeds the over current detection threshold for low side or high side, the MOSFET is tuned off for each oscillation cycle, and then turned on again after the dead time. If the overcurrent state persists, turning on/off is repeated. In addition, if this overcurrent detection state continues for the delay time for overcurrent set by the CR of the MODE pin, switching is stopped. When 810ms elapses after the switching is stopped, switching is resumed. Overcurrent detection state is reset if IS pin does not detect overcurrent for 76us.

(3)Advice on design

1.Overcurrent detection

The shunt capacitor C_{rd} is recommended to be approximately 1/100 of the resonant capacitor C_r. Overcurrent detection is performed by dividing the current by the capacitance ratio of C_{rd}/C_r, and converting the current into voltage using the current sensing resistor R_{IS}.

For example, to make overcurrent detection at I_{cr}=4A, the current is divided into 40mA by the capacitance ratio C_{rd}/C_r (1/100 recommended). See CA pin section how to decide the current sensing resistor.

2. Insert a CR filter

The switching noise of MOSFET may cause malfunction of the overcurrent detection function or the capacitive mode prevention function and operation may become unstable. In such cases, add a CR filter to the IS pin as shown in Fig. 40. The recommended value of CR filter is approximately C_{IS}=100pF and R_1=100ohm. Note that the overcurrent detection or the input power detection may be affected if the time constant of $R_1 \times C_{IS}$ is too large.

No.8 : VW pin

(1)Function

For the capacitive mode prevention function, the primary auxiliary winding voltage, which has the reversed polarity to the main winding, is input and the primary winding voltage is monitored on each switching cycles. (Voltage detection for the capacitive mode prevention function.)

(2) How to use

✓**Connection method**

The auxiliary winding voltage, which has the reverse polarity to the main winding, is input into VW pin through a resistor divider. The auxiliary winding for Vcc can be used for VW pin. To suppress noise, connect a capacitor between the VW pin and the GND. (See Fig. 53.)

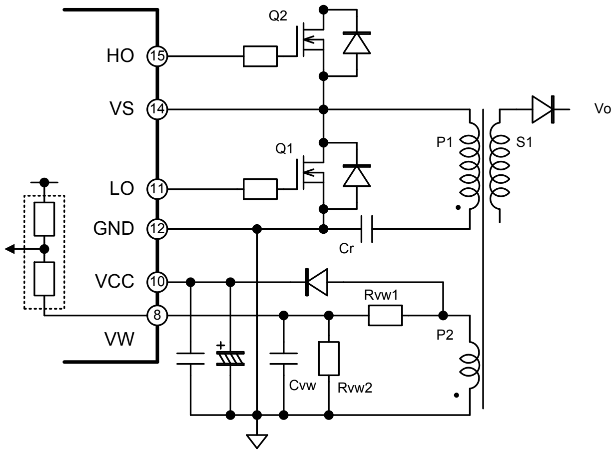


Fig. 53 VW pin circuit

✓**Operation**

Apply the auxiliary winding voltage, which has the reversed polarity to the main winding, to the VW pin. See “Capacitive mode prevention function” on page 34 for details of operation.

(3) Advice on design

1. Selection of VW pin resistor

How to decide the VW pin resistor is different between in auto standby operation and in standby operation by external signal.

In case of “standby operation by external signal”, select VW pin resistor by referring to the following values so that the VW pin voltage becomes approximately 3.5V during normal operation. However, make sure that the maximum absolute rating is not exceeded under any conditions including startup, stop, and overload.

[Reference resistance for “standby operation by external signal]

R_{VW1}: Approximately 6.8kΩ to 15kΩ

R_{VW2}: Fixed to 2.2kΩ

When Vcc winding is not used for the VW pin, select resistors so that the parallel combined resistance value of RVW1 and RVW2 becomes approximately 2kΩ and VW pin voltage becomes approximately 3.5V.

In case of “auto standby operation”, VW pin resistor is decided on the basis of the secondary diode current at standby mode. In the standby mode of “auto standby operation”, switching is controlled by CS pin at soft start/end, else by VW pin as shown in Fig. 16. VW pin controls switching frequency so that secondary diode peak current will be limited and audio noise from transformer will be suppressed at standby. To adjust the resistor divider of VW pin, secondary diode current should be monitored with maximum load at standby. Adjust R_{VW1} so that the secondary diode peak current will be approximately 10A. However, if the secondary diode peak current is too small, output power at one switching cycle become small and the number of the switching increases. As the result, ripple voltage of Vo will increase. Note it at adjustment.

2. Connecting the capacitor

Connecting a capacitor C_{VW} of 22pF (typ) to 56pF is recommended to suppress noise. If noise is large, thus causing malfunction, it is possible to increase the capacitance of C_{VW}. In this case, however, pay careful attention because it causes delay and the delay may cause malfunction in forced turn off function of the capacitive mode prevention.

No.9 CS pin

(1)Function

(i) Soft start during startup

(ii) Burst operation and soft start/end function in burst operation

(2)How to use

(i)Soft start during startup

✓Connection method

Connect a capacitor between the CS pin and the GND.

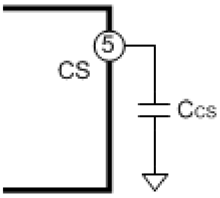


Fig. 54 CA pin circuit

✓Operation

Once the IC is activated, the CS pin source current (2.0μA or 4.0μA) is output from the CS pin to charge the capacitor connected between the CS pin and the GND. When the CS pin voltage rises to 0.4V, switching is started at 350kHz, and with the rise of the CS pin voltage, the operating frequency decreases, ensuring soft start. (See Fig. 10).

(ii) Standby mode operation and soft start/end function

✓Connection method

The same as the one described in (i).

✓Operation

In the low standby mode, the CS pin is charged/ discharged according to the FB pin voltage, ensuring burst operation. See page 31 for details.

(3)Advice on design

1. Capacitor value

Select the CS pin capacitor in the range described below.

[Standby operation by external signal]

Adjust the capacitor of the CS pin to be approximately from 0.01μF to 0.047μF considering the transformer audio noise and standby power at the standby mode.

[Auto standby operation]

In case of “auto standby operation”, adjust CS pin capacitor form 0.0047μF to 0.01μF.

2. Response switch circuit

As Fig. 44 on page 46, CS pin can be used as input signal for FB pin response switch circuit. The resistance set approximately 3MΩ not to affect the charge current.

No.10 : VCC pin

(1)Function

(i) Supplying the power of IC

(ii) Preventing malfunction by detecting low voltage

(iii) Overvoltage protection on the secondary side

(2)How to use

(i)Supplying power of IC

✓Connection method

Generally, the auxiliary winding voltage provided in the transformer is rectified/smoothed and connected. (See Fig. 55.)

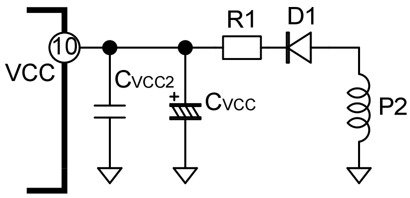


Fig. 55 VCC pin circuit

✓Operation

The voltage supplied from the auxiliary winding is optimum within the range from 14 to 27V during normal operation. Since the start-up circuit stop voltage is 11.6V (max.), the VCC pin voltage should be 14V or higher (recommended operation condition) with margin, not to allow the startup circuit to operate during normal operation.

It is impossible to keep operation of the IC only with the current supplied from the startup circuit, i.e. without using the auxiliary winding under normal operation conditions. Therefore, VCC voltage should be supplied from the auxiliary winding.

(ii) Preventing malfunction by detecting low voltage

✓Connection method

The same as the one described in (i) .

✓Operation

To prevent circuit malfunction when supply voltage decreases, an under voltage lockout circuit is incorporated. At the time of startup, switching is started when the VCC pin voltage increases to the start operation voltage of 14V. (It is also necessary that the voltage between the VB pin and the VS pin becomes V_{BS} switching start voltage of 8.8V or higher.) The VCC pin voltage decreases, and when it decreases to below 8.5V, the IC stops operating to prevent malfunction by the under voltage lockout circuit. When the IC stops operating the OUT pin is forcefully put in Low state. The latch mode of the protection circuit will also be reset.

(iii)Overvoltage protection on the secondary side

✓**Connection method**

The same as the one described in (i) .

✓**Operation**

If a state where the VCC pin voltage exceeds the over voltage threshold voltage of 30.6V continues for the overvoltage protection delay time of 304μs, the IC stops switching. Once switching is stopped, the VCC pin voltage is maintained within the range from 10V to 11V, and the state of stop is continued. When 810ms elapses after the switching is stopped, switching is resumed.

(3)Advice on design

1. Connection of the bypass capacitor

Since high current flows into the VCC pin to drive the MOSFET, relatively large noise tends to appear. In addition, the current supplied from the auxiliary winding may also cause the noise. If the noise is large, the IC may malfunction. Therefore, connect the bypass capacitor C_{VCC2}(0.1uF or larger) as close to the VCC pin as possible, in addition to the electrolytic capacitor C_{VCC} as shown in Fig. 55.

2. Auxiliary winding P_2

Determine the number of turns of the P_2 winding using the following formula. If the output voltage is V_O and the number of turns of the secondary winding is S_1, the number of turns of the P_2 winding can be calculated as follows:

$$P_2 = \frac{V_{CC}}{V_o} S_1$$

However, the coupling between the primary and the secondary of LLC transformer is not high. Therefore, the Vcc voltage on the actual PSU may be higher than the calculated value. It is necessary to evaluate and adjust on the prototype PSU.

3. Rectifier diode and resistors, and electrolytic capacitor

In the VCC supply circuit shown in Fig. 55, use the rectifier diode D_1 with low forward.

When using low standby mode, to prevent the VCC voltage from decreasing while switching is stopped, it is necessary to adopt a rather large VCC pin capacitor.

No.11 : LO pin

(1)Function

This pin drives the MOSFET of low side.

(2)How to use

✓**Connection method**

LO pin is connected to the MOSFET gate via resistors.

(See Fig. 56 and 57.)

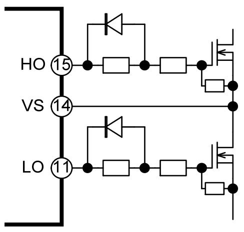


Fig. 56 Gate circuit 1

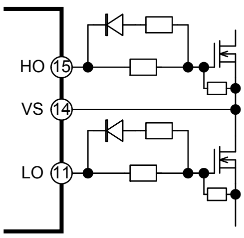


Fig. 57 Gate circuit 2

✓**Operation**

During period when the MOSFET is on, the state is set to H level and almost the VCC voltage is output.

During the period when the MOSFET is off, the state is set to the L level and the voltage of almost 0V is output.

(3)Advice on design

Gate resistors is connected to limit the OUT pin current and prevent the oscillation of the gate pin voltage.

No.12 : GND pin

(1)function

This is the GND pin of the IC and the reference for the voltage of each part of the IC.

(2)Advice on design

Both control circuits and low side gate driver circuit use this pin as GND. Therefore, the impedance of GND wiring should be as low as possible.

No.13 : NC pin

Since this pin is placed adjacent to the high-voltage pin(VS), it is not connected to inside the IC.

No.14 : VS pin

(1)Function

This pin is the floating GND for the high-side driver.

(2)How to use

✓Connection method

In the power stage section of the current resonance circuit, the high-side MOSFET source and the low-side MOSFET drain is connected. Connect VS pin to the node with low impedance wiring. (See Fig. 58.)

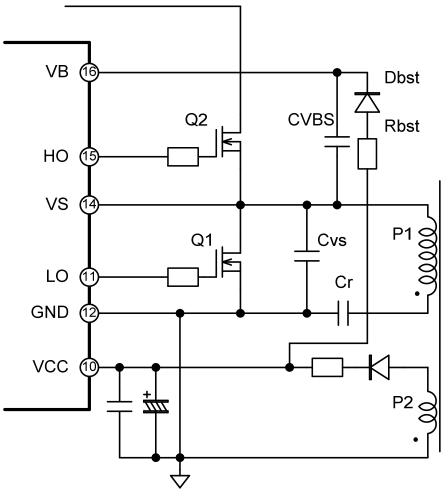


Fig. 58 bootstrap circuit

✓Operation

Since the high-side MOSFET and the low-side MOSFET turns on and off alternately, the VS pin voltage goes high and low. With bootstrap circuit, high side driver circuit operates using this pin as floating GND.

(3)Advice on design

Just after the high side MOSFET turns off, current path of the primary main circuit is changed from the high side MOSFET to the body diode of the low side MOSFET. At that time, VS pin voltage drops below GND by tens of volts for hundreds of ns due to the wiring inductance and current change rate. This negative voltage may exceed the absolute maximum rating and may cause malfunction or damage of the IC. In order to prevent it, therefore, connect a capacitor C_{VS} between VS pin and GND to reduce switching speed or reduce wiring inductance. However, too large C_{VS} may causes hard switching. Decide C_{VS} after the evaluation using an actual power supply. (Recommended : 100pF - 1000pF)

No.15 : HO pin

(1)Function

This pin drives the high side MOSFET.

(2)How to use

✓Connection method

HO pin is connected to the MOSFET gate via resistors. (See Fig. 56 and 57.)

✓Operation

During the period when the MOSFET is turned on, the state is set to the H output state and almost the VB voltage is output. During the period when MOSFET is turned off, the state is set to the L output state and almost the VS voltage is output.

(3)Advice on design

Gate resistors are connected to limit the OUT pin current and prevent the oscillation of the gate pin voltage.

When the minimum dead time t_D is larger than the appropriate dead time, delay the turn-off and decrease effective dead time by adjusting the gate resistance.

No.16 : VB pin

(1)Function

(i) Power supply pin of the high-side driver.
(ii) Detects low voltage to prevent malfunction.

(2)How to use

(i) Supplies power to the high-side driver

✓Connection method

The bootstrap capacitor C_{VBS}, the bootstrap diode D_{bst} and the charge-current limiting resistor R_{bst} is connected as shown in Fig. 58.

✓Operation

During the period when the low-side driver is on, the bootstrap capacitor C_{VBS} is charged from the VCC pin via the bootstrap diode D_{bst}. The high-side driver operates using this electric charge.

(ii) Detecting low voltage to prevent malfunction

✓Connection method

The same as the one described in (i) .

✓Operation

To prevent malfunction at the time of decreased power supply voltage, an under voltage lockout circuit is integrated. When the voltage between the VB pin and the VS pin increases and reaches the V_{BS} switching start voltage of 8.8V, switching is started (it is also necessary for the VCC pin voltage to exceeds the switching start voltage of 9V). When the VCC power supply voltage decreases and the voltage between the VB pin and the VS pin decreases to the V_{BS} switching stop voltage of 7.5V, the IC operation stops.

In a state where the under voltage lockout circuit is actuated and the IC operation is suspended, the HO pin is forced to be in the Low state.

(3)Advice on design

The loop consisting of the bootstrap capacitor C_{VBS}, VS pin and VB pin should be as small as possible.

1. Selecting a bootstrap capacitor C_{VBS}

In Fig. 58, when Q_2 is on and Q_1 is off, the C_{VBS} voltage decreases due to the Q_1 gate charging current, the high-side operating current of IC I_{BS2}, and C_{VBS} leakage current. Therefore, select C_{VBS} so that the voltage between the VB pin and the VS pin will not drop below the V_{BS} switching stop voltage of 8.1V ($V_{BSOFF(max.)}$). The minimum capacitance required for C_{VBS} is calculated using the following formula and select the capacitance with sufficient margin. A bootstrap capacitor C_{VBS} of 0.1uF (min.) – 1.0uF (max.) is recommended.

$$C_{VBS} > \frac{Qg + I_{IBS2} \times Ton + Icbs(leak) \times Ton}{V_{CC} - V_{BSOFF} - Vf - V_{LS}}$$

Q_g: Gate charge quantity of MOSFET
I_{BS2}: High-side operating current of IC
T_{on}: Maximum ON time of high-side MOSFET Q_2
$I_{cbs(leak)}$: Leakage current of bootstrap capacitor
V_{CC}: Low-side power supply voltage
V_{BSOFF}: VBS switching stop voltage
V_f: Forward voltage of bootstrap diode
V_{LS}: Low-side MOSFET Q_1 ON voltage
Example:

$$C_{VBS} > \frac{100nc + 0.1mA \times 5us + 0.01uA \times 5us}{15V - 8.1V - 0.6V - 5V} = 0.08\text{uF}$$

2. Selecting a charging current limiting resistor R_{bst}

Be sure to insert R_{bst} to prevent rush current at initial charging of C_{VBS}. To prevent damage of the diode D_{bst}, select R_{bst} so that the rush current will be below the rating peak current of the selected diode.

3. Selecting bootstrap diode D_{bst}

Select a fast-recovery diode of short reverse recovery time. If the reverse recovery time is long, the reverse recovery current to the low-side power supply V_{CC} increases when the high-side MOSFET is turned ON and high side Vcc may drops. In addition, high side Vcc ripple may cause malfunction.

As for rating voltage, select a diode of the same or higher rating voltage of that of the low-side MOSFET, taking derating into consideration.

The average current I_{FAV} can be found by multiplying the gate charge quantity Q_g of the MOSFET by the operation frequency f_{sw} .

The peak current is considered to be the current found by dividing the maximum low-side power supply voltage value V_{CC} by R_{bst}.

Other advice on design

(1) Preventing malfunction due to negative voltage of the pin

If large negative voltage is applied to each pin of the IC, the parasitic devices inside the IC may be operated, thus causing malfunction. Confirm that the voltage of -0.3V or less is not applied to each pin.

If negative voltage is applied due to noise, connect a Schottky diode between each pin and the GND.

The forward voltage of the Schottky diode can suppress the negative voltage at each pin. In this case, use a Schottky diode whose forward voltage is low.

10. PCB layout guideline

In the switching power supply, large pulse current flows through the GND wiring and surge voltage (noise) is generated. The noise may causes malfunction of the IC. (unstable voltage, unstable waveform, abnormal latch stop, etc.) Malfunction may also be caused by injected surge voltage/current such as lighting surge test, AC line surge test and electrostatic discharge test.

Please design the PCB layout and the wiring with consideration of the followings to prevent the malfunction.

Current path in switching power supply

(1) Main circuit current which flows from input smoothing capacitor to transformer primary winding, MOSFET and current sense resistor.
(2) Current which flows from auxiliary winding to VCC capacitor and driving current which flows from IC to the MOSFET
(3) Control circuit current around the IC such as feedback signal
(4) Filter current which flows between primary and secondary via the Y-Capacitor.

Points in pattern designing

- The GND wiring of the above (1)-(4) should be separated so as not to affect each other.
- To minimize the surge voltage of MOSFET, loop length of the main circuit should be designed as short as possible.
- Especially separate the GND patterns in the main circuit system and the control circuit system from each other, and connect the GND patterns as near the (-) pin of the electrolytic capacitor as possible.
- The electrolytic capacitor between VCC pin and GND should be connected close to the IC.
- The bypass capacitor of the VCC pin should be connected as close as possible to the IC.
- The bootstrap capacitor between the VB – VS pins should be connected close to each pin using the shortest wiring.
- Capacitors for filter such as FB pin and CS pin should be connected close to each pin using the shortest wiring.
- The loop area of IS pin and GND wiring should be as small as possible.
- The IC and control circuit should not be arranged inside the main circuit loop.
- Control circuit and signal wiring should not be placed under the transformer and coil so as not to affect the leakage flux.

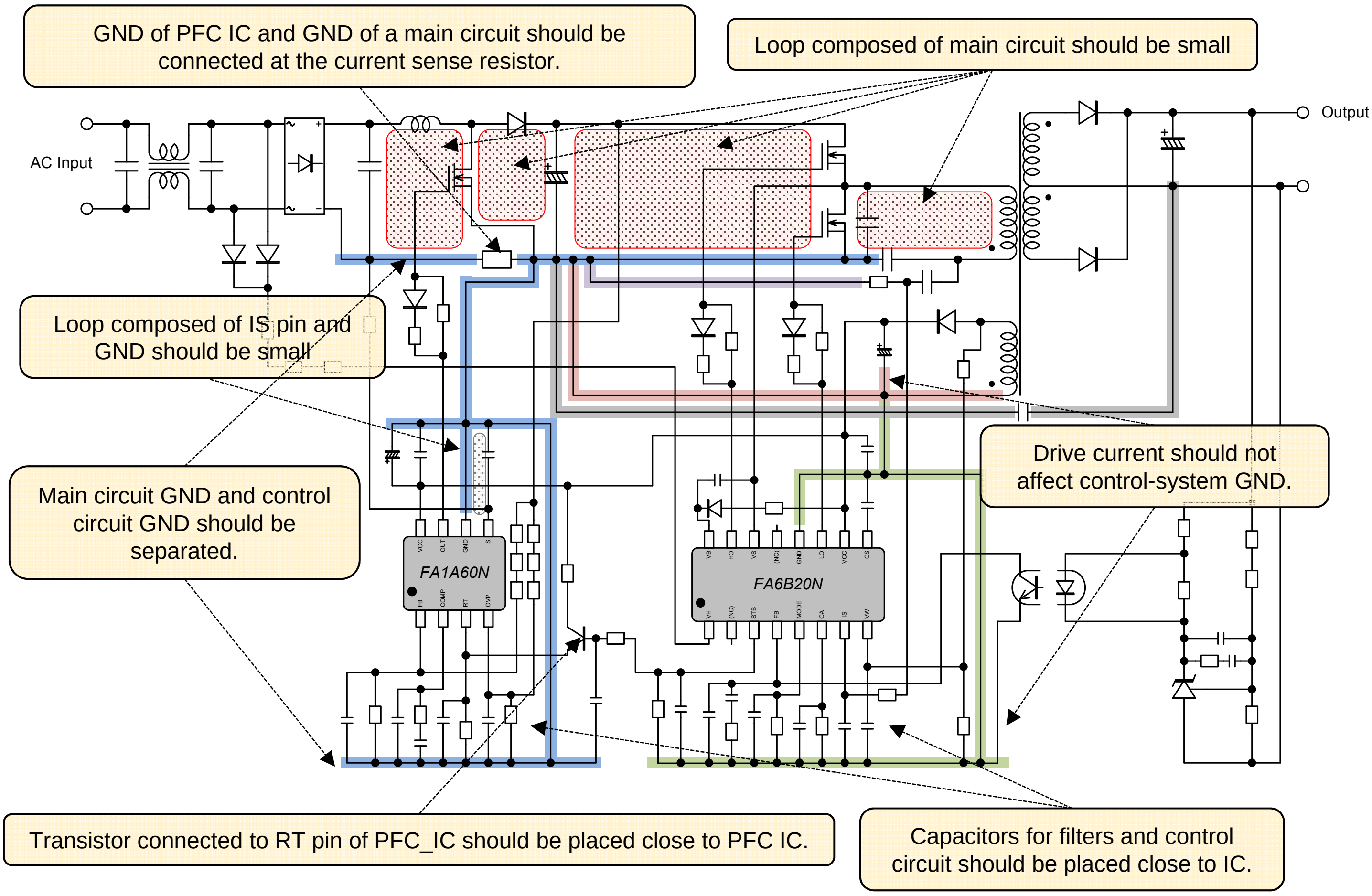


Fig. 59 PCB wiring design guide

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