Intelligent Digital Multi-Mode Flyback Controller HY1602

Revision 1.9
Documentation number: DS-HY1602-R19

Contents

Intelligent Multi-Mode Flyback Controller

Features

- Intelligent Digital Multi-Mode Control
- Peak Current Mode Control at Burst-Mode /PFM/DCM/CCM
- Continuous-Conduction Mode (CCM) at Low Line(LL), QR at High Line(HL) to Balance the Switching Loss and the Conduction Loss
- Over-load Period up to 56ms
- Switching Frequency Dithering to Improve EMI
- Adaptive MOSFET Gate Drive to Balance Switching Loss and EMI
- MOSFET Gate Voltage is Clamped at 12V
- Meet Limited Power Source (LPS) safety requirements
- Rich Protection Features
  - Output OVP
  - VCC OVP
  - Transformer Saturation Protection
  - Output Short Circuit Protection
  - Current Sensor Resistor Short Protection
  - Output Open Loop Protection
  - On Chip OTP
- Line Feed-forward Compensation
- Brown-in and Brown-out
- Power Consumption < 75mW
- Low Start-Up Current (<3 µA)

Description

HY1602 is an intelligent digital multi-mode Flyback controller. The newly developed architecture is inherent features to meet regulatory requirements from around the world.

HY1602 integrates rich protections and features such as line compensation, slope compensation, transformer short protection, output over-voltage protection, over-temperature protection, brown in and brown-out, sense resistor short protection.

HY1602 has 2 options:

HY1602A: 65kHz, VCC OVP Auto Restart, Output OVP Auto Restart, CV/LPS

HY1602B: 89kHz, VCC OVP Latch, Output OVP latch, CV/LPS

HY1602A/B is available with the SOT23-6 package.

Applications

- Offline Charger
- Programmable travel adapter
- USB PD Charger
- TV / Monitor Standby Power
- Notebook Adapter

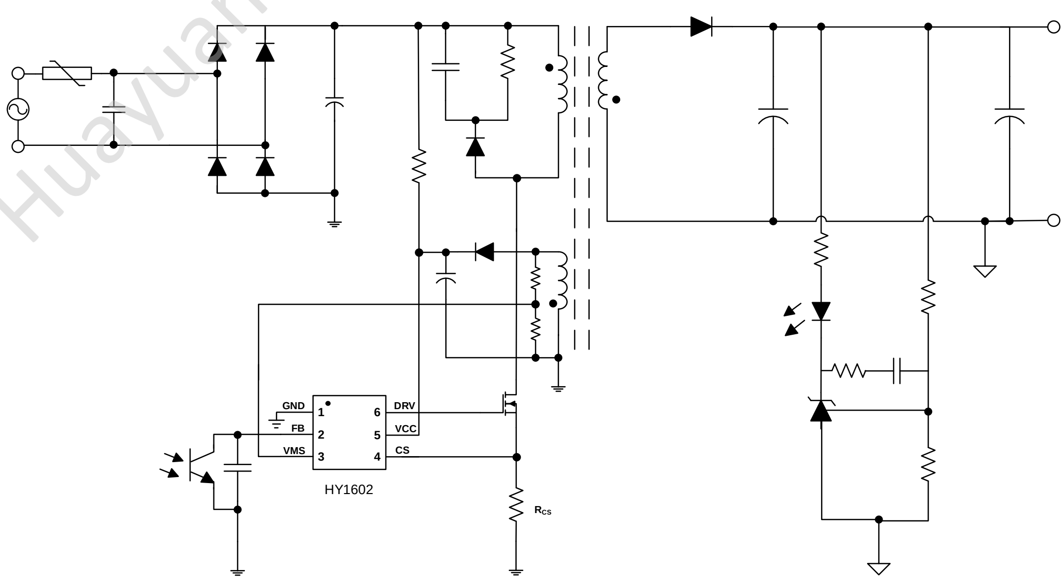


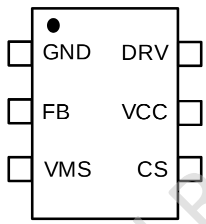
Fig 1.Typical Application Circuit

HY1602 Option Table

Product		HY1602A	HY1602B
Switching Frequency	Low Line	65 kHz	89 kHz
	High Line	65 kHz	89 kHz
VCC OVP		Auto Restart	Latch
Output OVP		Auto Restart	Latch

Pin Configuration

(TOP VIEW)



SOT23-6

Functional Pin Definitions

No.	Name	Description
1	**GND**	Ground.
2	**FB**	Voltage loop feedback input. Connect an opto-coupler from the FB pin.
3	**VMS**	Auxiliary winding detection signal input. It detects the input voltage and output voltage information
4	**CS**	Current sensing input.
5	**VCC**	VCC is the supply of IC. The controller is enabled when VCC voltage reaches V_{CC_ON} and disabled when VCC drops below V_{CC_UVLO}.
6	**DRV**	Gate drive output

IC Functional Diagram

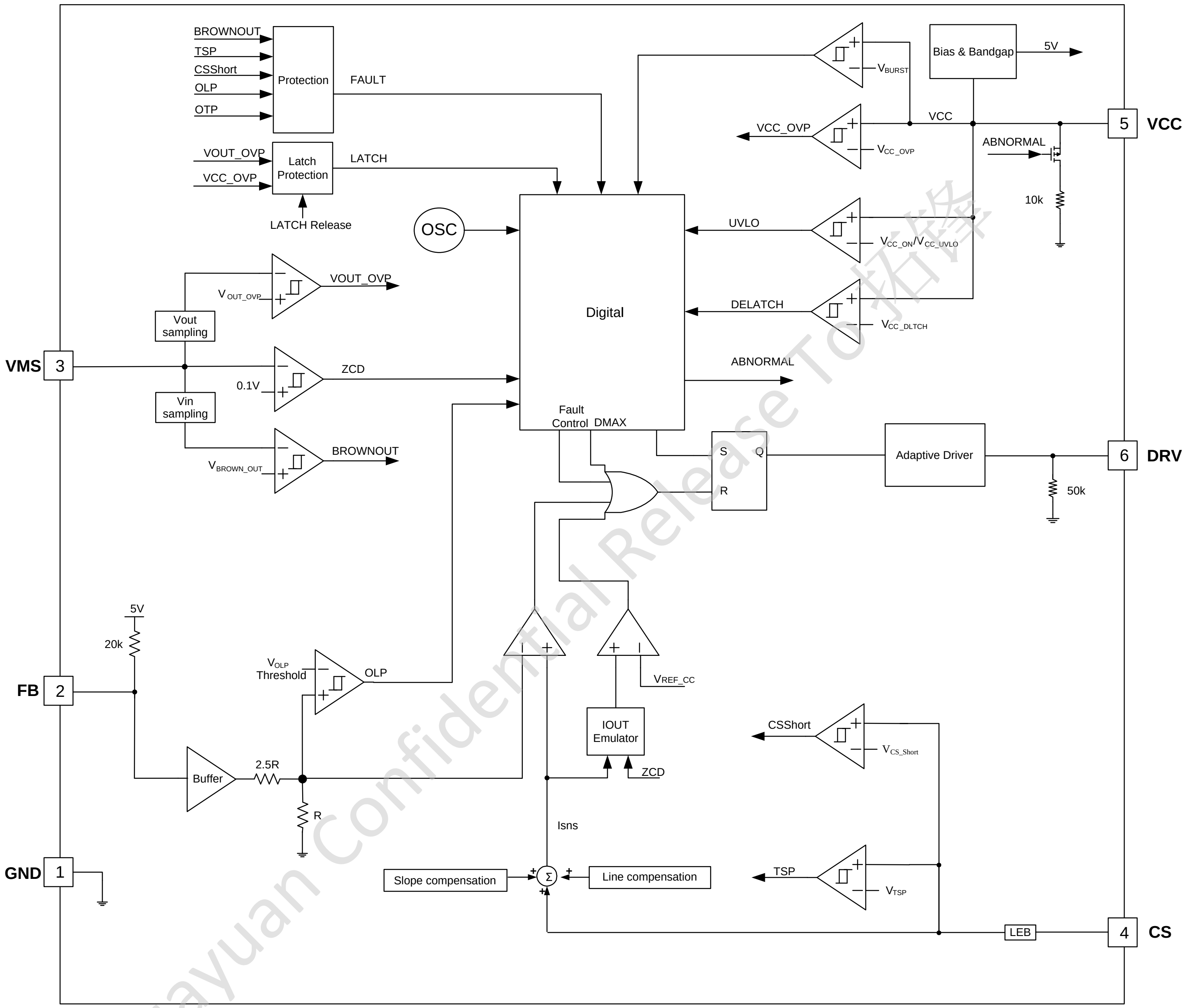


Fig 2. HY1602 Simplified Functional Block Diagram

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Min.	Max.	Unit
VCC	VCC	-0.3	35.0	V
DRV	DRV	-0.3	35.0	V
CS, FB, VMS	CS, FB, VMS	-0.3	6.5	V
T_{jct}	Operating junction temperature	–40	150	℃
T_{stg}	Storage temperature	–40	150	℃

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.

ESD Ratings

Item	Description	Value	Unit
Electrostatic Discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001	±4000	V
	Charged device model (CDM), per JEDEC specification JESD22-C101	±1000	V

Thermal Specification (Note 2)

Item	Value	Unit
RθJA Junction-to-ambient thermal resistance	260	℃/W
RθJC(top) Junction-to-case (top) thermal resistance	135	℃/W

Note 2: The maximum allowable power dissipation is a function of the maximum junction temperature $T_J(MAX)$, the junction-to-ambient thermal resistance $R_{\theta JA}$, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_D(MAX)=(T_J(MAX)- T_A)/R_{\theta JA}$. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

Electrical Characteristics

VCC = 12V, T_{AMB}= 25 ℃, unless otherwise specified.

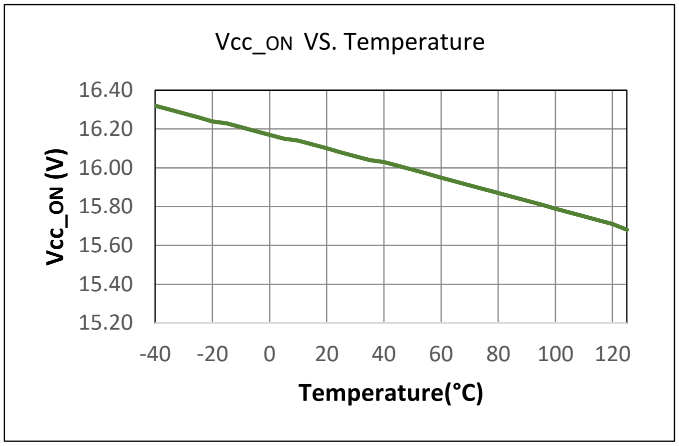
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
VCC Section						
V_{CC}	Bias Power Supply				33	V
V_{CC_OVP}	VCC OVP Threshold		28	30	32	V
V_{CC_ON}	Power-On Threshold	V_{CC} Rising	15.0	16.5	17.5	V
V_{CC_UVLO}	UVLO Threshold	V_{CC} Falling	6.7	7.50	8.3	V
V_{CC_DLTCH}	Delatch Threshold	V_{CC} Falling		4.50		V
I_{CC_NGT}	Quiescent Current	DRV Pin Open			700	µA
I_{CC_WGT}	Operating Current with Load	fs=65kHz, 1nF Load on DRV Pin		2		mA
I_{CC_ST}	Start_up Current	V_{CC}< V_{CC_ON} During Start_up			3	µA
CS Section						
V_{CS_Limit}	Current Limit		0.76	0.80	0.84	V
V_{CS_Short}	Current Sensing Short Threshold		0.06	0.10	0.14	V
V_{TSP_REF}	Transformer Saturation Protection Threshold	HY1602A/B	1.14	1.20	1.26	V
LEB	Leading Edge Blanking Time			300		ns
V_{REF_CC}	Constant Current Reference		324	360	396	mV
FB Section						
V_{FB}	FB Pin Pull-Up Voltage	FB Pin Open		5.0		V
V_{FB_OLP}	Open Loop Protection Reference		4.0	4.2	4.4	V

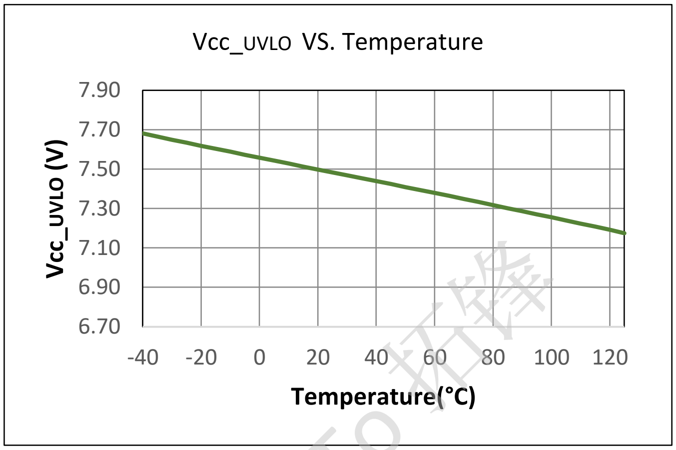
V_{OLP_HYS}	Open Loop Protection Hysteresis			40		mV
V_{BURST}	Burst Mode Entry Threshold		1.15	1.2	1.25	V
V_{BURST_HYS}	Burst Mode Threshold Hysteresis			0.1		V
R_{FB}	FB Pin Pull_up Resistance		14	20	26	kΩ
VMS Section						
V_{SNS}	Maximum Voltage				5.5	V
$V_{OUT\_OVP\_REF}$	Output Voltage OVP Reference		2.35	2.5	2.65	V
I_{BRWO_REF}	Input Line Voltage Brown Out Reference			72.0		μA
I_{BRWI_REF}	Input Line Voltage Brown In Reference			100		μA
I_{HL_LL}	High/Low Line Detection Reference			218		μA
T_Vsns_blk	Vsns blanking time	V_{FB} >1.75V		2.5		μs
		V_{FB} <1.5V		1.4		μs
DRV Section *						
V_{DRV_CLP}	DRV Clamped Voltage			12		V
R_{ON_PUP}	Pull_up R_{DS_ON}			180		Ω
R_{ON_PDW}	Pull_down R_{DS_ON}			26		Ω
T_{RISE}	Output Rising Time, 10% to 90%	C_L=1nF		200	300	ns
T_{FALL}	Output Falling Time, 90% to 10%	C_L=1nF		50	100	ns

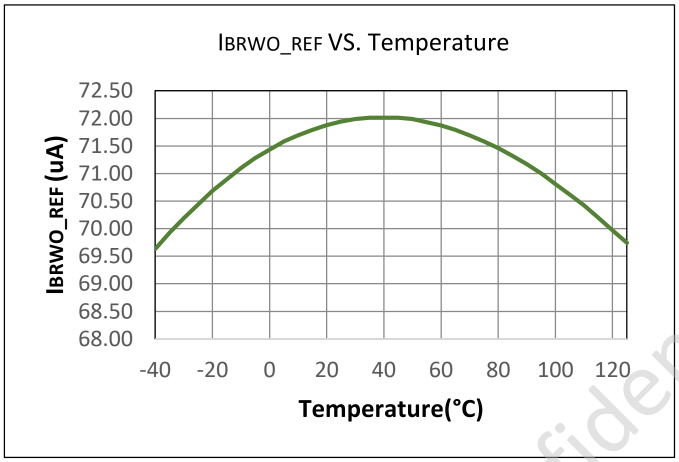
T_{ON_MIN}	Minimum PWM ON			600		ns
T_{OFF_MIN}	Minimum PWM OFF			2.6		μs
PWM Section						
f_{SW}	Base Switching Frequency	HY1602A	60	65	70	kHz
		HY1602B	80	89	96	kHz
f_{MIN}	Minimum Switching Frequency		22	25	28	kHz
Δf	Frequency Jittering Range			±5%		
OTP Section						
T_{OTP}	Over Temp Protection	Junction Temperature(Note 3)	140			℃
T_{OTP_HYS}	OTP Hysteresis	(Note 3)		50		℃

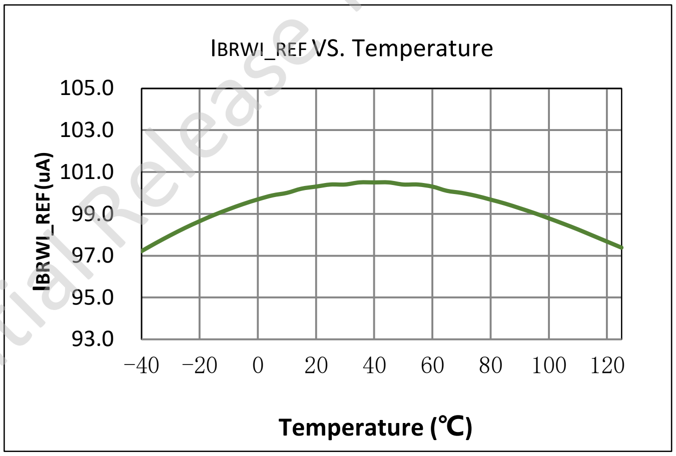
Note 3. Guaranteed by design

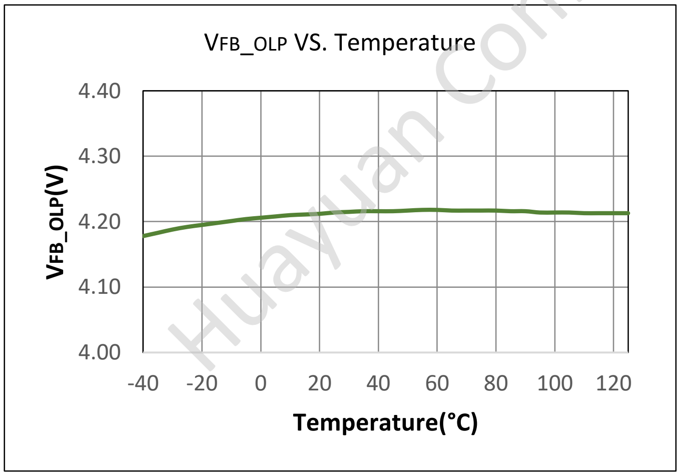
Typical Characteristics

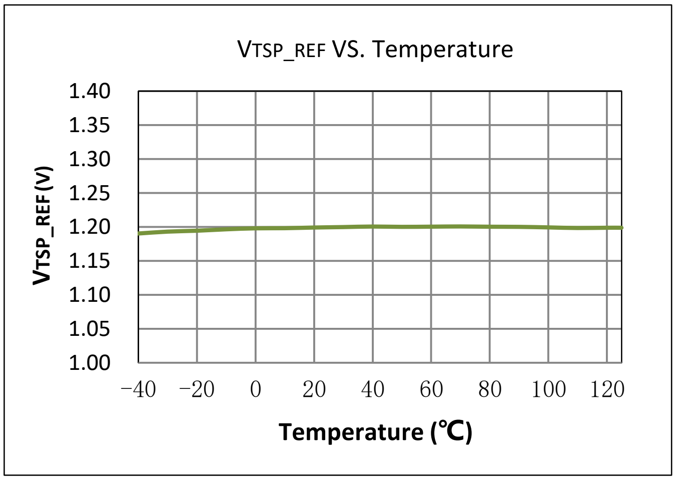


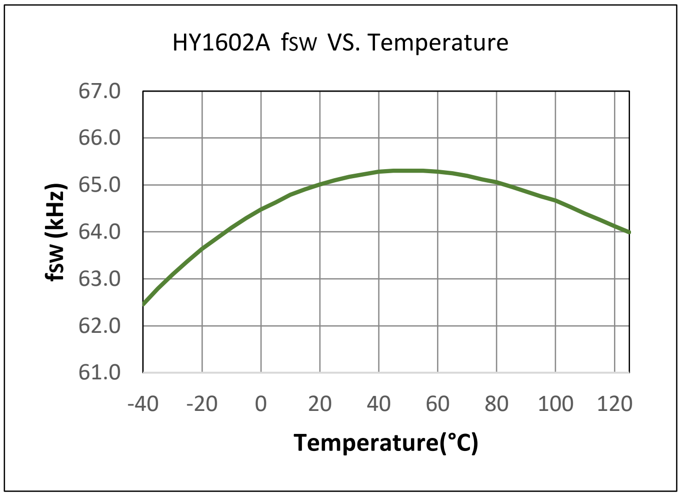


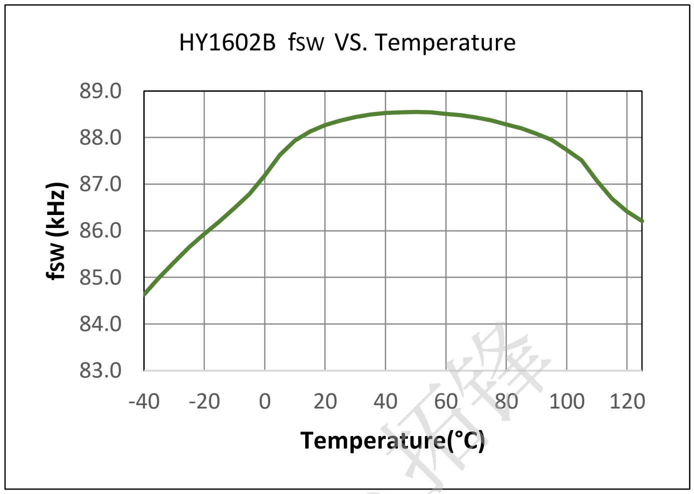









HY1602A fsw VS. Temperature
fsw (kHz)
67.0
66.0
65.0
64.0
63.0
62.0
61.0
-40
-20
0
20
40
60
80
100
120
Temperature(°C)


HY1602B fsw VS. Temperature
fsw (kHz)
89.0
88.0
87.0
86.0
85.0
84.0
83.0
-40
-20
0
20
40
60
80
100
120
Temperature(°C)

Detailed Function Description

HY1602A/B is a high performance, high integration, secondary side feedback AC/DC Flyback PWM controller. It implements the advanced digital control scheme to achieve high efficiency, better EMI and high performance at low total system cost. HY1602A/B operates at Quasi-Resonant (QR) mode under high line. It operates CCM under low line condition in order to improve efficiency and reduce bulk capacitance.

Multi-Mode

HY1602A/B is a digital multi-mode PWM controller. It operates Burst/PWM/PFM/QR/DCM/CCM control alternately based on the line input voltage, feedback voltage, as shown in Fig 3 and Fig 4 . Under high line condition, it operates at QR mode. Under low line condition, it operates at CCM with switching frequency at 65kHz/89kHz. As the load decreases, it enters into DCM operation. The switching frequency is decreased from 65 kHz/89 kHz to 25 kHz following the frequency profile. At light load, the controller operates at the burst mode.

The high line or low line input can be determined by the HL/LL threshold on VMS. The maximum switching frequency at the high line is fixed at 65kHz/89kHz. The low line mode can operate CCM mode with 65kHz/89kHz.

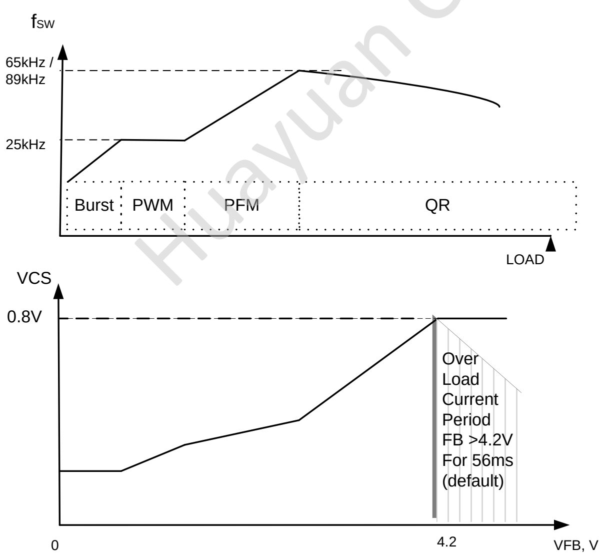


Fig 3.High Line Load Profile

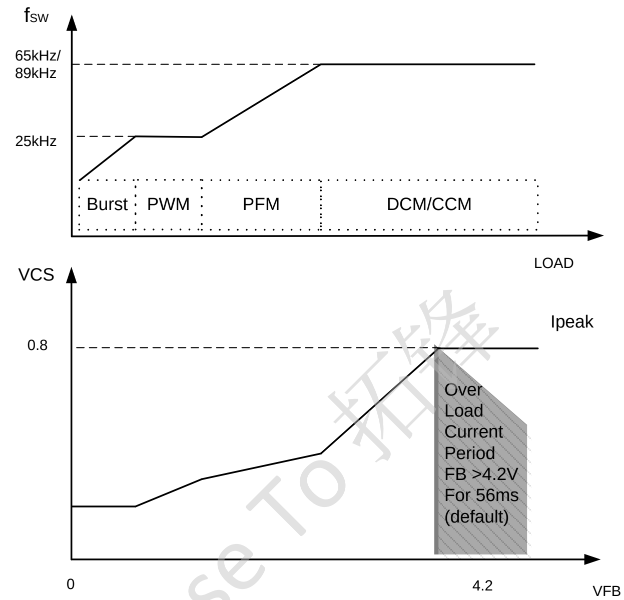


Fig 4. Low Line Load Profile

Start-up

The start-up time specification of adapter is generally less than 3 seconds. The V_{CC} voltage of the HY1602A/B generated from start-up resistors and the bias winding after start-up. HY1602A/B consumes less than 3μA current (I_{CC_ST}) till V_{CC} reaches the threshold of V_{CC_ON}. It enables all internal block bias based on power sequence and MOSFET driver. As the output voltage is ramping up, the bias winding voltage is going up accordingly. The V_{CC} voltage is going down from V_{CC_ON} once the normal operation begins till the bias voltage takes over to charge the V_{CC} capacitor.

Soft Start

After V_{CC} reaches V_{CC_ON} threshold, HY1602 begins the soft start.

The HY1602 soft start threshold and timing is show in Fig 5.

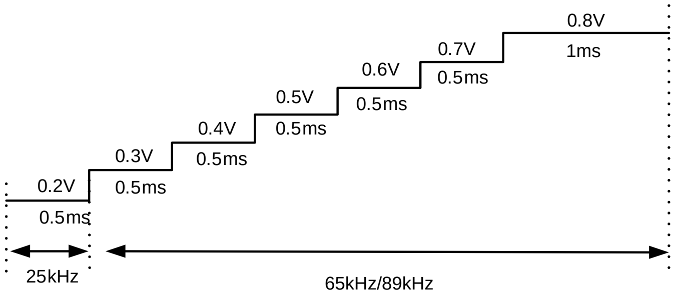


Fig 5. Soft-Start with 4ms Timing and Threshold

In HY1602A/B, the soft start is implemented as a predetermined peak current control within 4ms. For first 0.5ms, the switching frequency is 25kHz and the predetermined peak current control voltage command across sensing resistor is 0.2V in order to achieve the transformer demagnetizing. The next level is the peak current control voltage as 0.3V for 0.5ms under 65kHz/89kHz switching frequency. The following peak current control voltage step is increasing 0.1V for every 0.5ms to 0.8V following the incremental pattern. The duration of 0.8V step is 1ms instead of 0.5ms. During the soft start, the feedback voltage and the peak current control are decoupling. The soft start will be terminated once the feedback voltage is lower than the predetermined peak current level.

Line Compensation

HY1602A/B implements the line compensation scheme to add the offset voltage on CS pin in order to compensate the turn off delay, as shown in Fig 6. This line feedforward compensation is able to maintain the same output power under all range of input voltage condition.

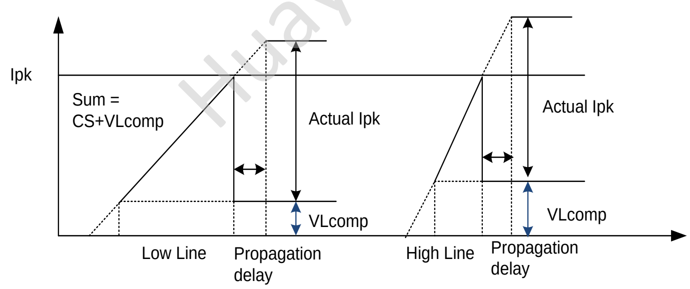


Fig 6. Line Compensation

HY1602A/B indirectly senses the input line. When the MOSFET is on, the bias winding has a negative voltage by the primary to bias winding ratio. The current on the VMS is calculated by VMS voltage divided by R_{UP} Resistor. The internal current source corresponds to the DC bulk voltage through the bias winding.

$$I_{VIN} = \frac{N_B}{N_P} \cdot \frac{V_{BULK}}{R_{UP}}$$

Where N_B is the bias winding turn number, N_P is the primary turn number, R_{UP} is the top resistor of the bias winding resistor divider, V_{BULK} is the bus voltage after the bridge. The resistor divider is shown in Fig 7. The reference current thresholds related bias winding resistor divider is listed in table as below:

Input Line Voltage Brown Out Reference	72 μA
Input Line Voltage Brown In Reference	100 μA
High/Low Line Detection Reference	218 μA

Limited Power Source (LPS)

Power supply designed for 20V/3A may generally delivery current of 12A when output is down to 5V, under keeping constant output power operation. Thus, violate the Limited Power Source (LPS) safety requirements for the maximum output current, and may damage its connected devices. In order to achieve reliable operation, HY1602A/B employs innovative schemes to measure output current without directly sensing output current.

In DCM flyback converter, the output average current, Io,

$$I_O = \frac{1}{2} \cdot N \cdot \frac{Vcs}{Rcs} \cdot \frac{T_{rst}}{T_p}$$

Define an internal CC reference voltage of V_{REF_CC} as the constant value and can be used to determine the maximum output current.

$$V_{REF\_CC} = I_{out} \cdot \frac{Rcs}{N}$$

Protections

HY1602A/B achieves various protections as listed in below table, including VCC OVP, Output OVP, RCS Short Protection, Transformer-Short Protection (TSP), Over Load Protection (OLP), Over-Temperature Protection (OTP), Brown-Out/in Protection.

Protection	Response
VCC OVP	1602A: Auto restart
	1602B: Latch
Output OVP	1602A: Auto restart
	1602B: Latch
R_{CS} Short Protection	Auto restart
Transformer Saturation Protection TSP	Auto restart
Over Load Protection	Auto restart
On Chip OTP	Auto restart
Brown Out/In	Auto restart

VCC OVP

When VCC pin voltage reaches threshold, V_{CC_OVP}, HY1602 performs VCC OVP protection function. For HY1602A, VCC_OVP is an auto restart type protection. For HY1602B, VCC_OVP is latch type protection and de-latched after AC recycle when V_{CC} voltage is discharged below V_{CC_DLTCH}.

Output OVP Protection

The output voltage is sensed from the auxiliary winding on the VMS pin. The voltage level is detected from the rising edge of VMS after debounce time. The voltage level is compared with the OVP threshold ($V_{OUT\_OVP\_REF}$). If the voltage level is above the OVP threshold, HY1602A shuts down the gate signal and enters into auto restart mode. Under auto restart mode, HY1602A gate signal recovers once the OVP threshold is not triggered. Different from HY1602A, HY1602B shuts down the gate signal and enters into latch mode. This latch is released with AC power off and V_{CC} voltage is discharged below V_{CC_DLTCH}.

R_{CS} Short Protection

If R_{CS} is shorted, the system might damage. To prevent the damage, HY1602A/B implements the scheme to detects R_{CS} short and shut down the PWM.

Transformer Saturation Protection (TSP)

TSP is performed when there is a transformer saturation. It could happen when both secondary rectifier and primary MOSFET turns on overlap. It is implemented through the comparator with V_{TSP_REF} threshold. The current slew rate is very high under the transformer saturation as only leakage inductance limits the transformer current rate. If current sensing voltage signal triggers TSP threshold after LEB. IC performs TSP to shut down the PWM signal immediately once the TSP threshold is triggered after 3 consecutive trigger events, HY1602 keeps as off state till next power reset event.

Over Load Protection (OLP)

The maximum current sense voltage is limited at V_{CS_LIMIT}. When the current sense voltage reaches at V_{CS_LIMIT}, and the switching frequency also reaches the f_{SW}, the maximum output power is limited. If the output load keeps increasing, the output voltage keeps dropping, then the feedback voltage V_{FB} keeps increasing, when the V_{FB} reaches the V_{FB_OLP}, HY1602 counts to 56ms and then shuts down. The OLP function is enable after the soft-start.

When the feedback circuit such as opto-coupler opens, V_{FB} pin is pulled up to the internal 5V reference. HY1602 also shuts down after 56ms.

Over Temperature Protection (OTP)

The internal die temperature is sensed to prevent from over-heat. The temperature reference for OTP is defined at 145 ℃ typical with 50 ℃ hysteresis. When OTP fault signal is detected, the OTP is activated to shut down PWM. HY1602A/B try to power-up until the die temperature drops down to 95 ℃.

Brown Out and Brown In

HY1602A/B detects brown out and brown in condition through the current output from VMS pin under normal operation. When the current from VMS pin to the bias winding below I_{BRWO_REF}, the brown out condition triggers. The PWM is shut down after debounce time once brown out condition triggers. When the current from VMS pin to the bias winding is above I_{BRWI_REF}, the brown in condition triggers.

Bias winding resistor divider circuit is used to detect output voltage, input voltage brown out/brown in and high line/low line conditions, as shown in Fig 7.

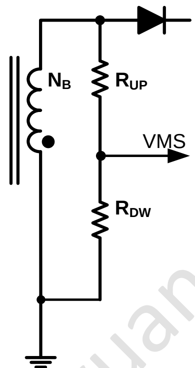


Fig 7.Bias Winding Detection Circuit

The typical bottom resistor value is calculated based on V_{BRWO} as:

$$R_{DW}=\frac{V_{OUT\_OVP\_REF}\times V_{BRWO}\times\frac{N_B}{N_P}-0.15\times(V_{OUT\_OVP}\times\frac{N_B}{N_S}-V_{OUT\_OVP\_REF})}{I_{BRWI\_REF}\times(V_{OUT\_OVP}\times\frac{N_B}{N_S}-V_{OUT\_OVP\_REF})}$$

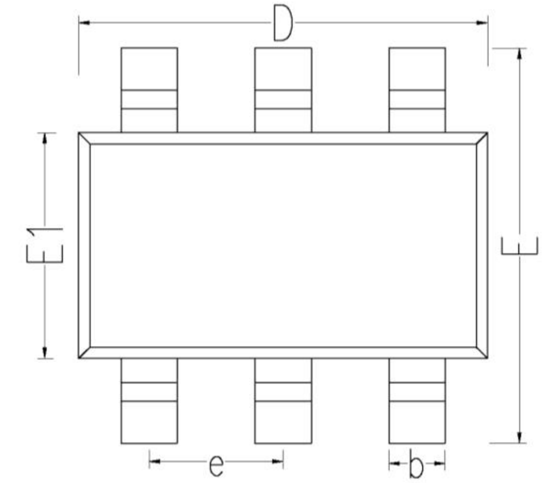
Where, V_{BRWO} is the brown out voltage on the bus after the bridge, V_{OUT_OVP} is the output OVP voltage, N_B is the bias winding turn number, N_P is the primary side turn number, N_S is the secondary side winding turn number.

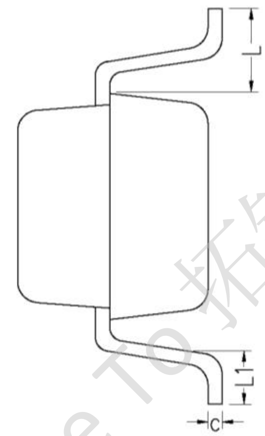
The typical top resistor value is calculated as:

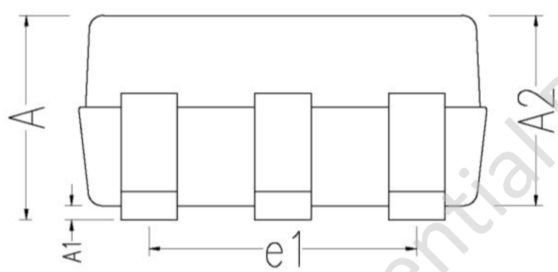
$$R_{UP}=\frac{V_{BRWO}\times\frac{N_B}{N_P}}{I_{BRWI\_REF}+\frac{0.15}{R_{DW}}}$$

In the practical design, the resistor of the divider is round to the closest standard resistance value.

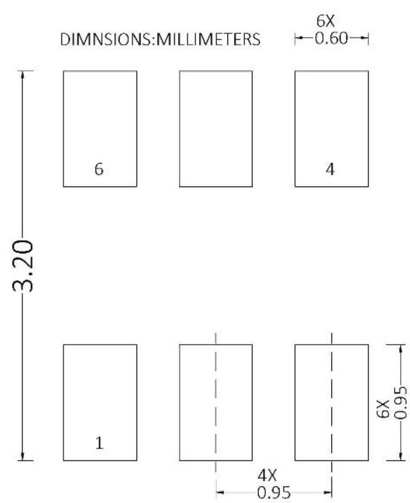
SOT23-6 Package





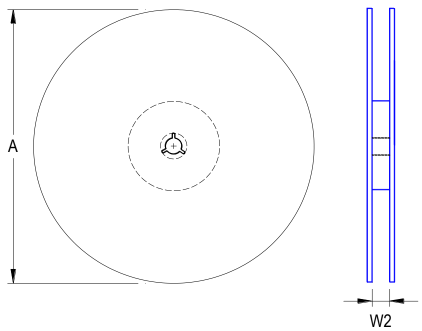


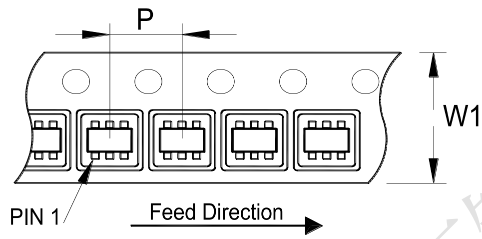
COMMON DIMENSIOS(millimeter)			
SYMBOL	MIN	NOM	MAX
A	-	-	1.45
A1	0	-	0.15
A2	0.90	-	1.30
b	0.30	-	0.50
c	0.08	0.13	0.20
D	2.65	2.90	3.15
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	0.95REF		
e1	1.90REF		
L	0.50	0.60	0.70
L1	0.30	0.45	0.60



Recommended Land Pattern

Tape and Reel Information





Package Type	Tape Size (W1) (mm)	Pocket Pitch (P) (mm)	Reel Size (A)		Q'ty Per Reel pcs	Reel Width (W2) Min./Max. (mm)
			mm	inch		
SOT23-6	8	4	180	7	3000	8.4/9.9

Packing Information

Item	Package	Pcs/reel	Reel/Reel box	Reel Box Size (mm)	Reel box/Carton Box	Carton Box Size(mm)	Pcs/carton Box
1	SOT23-6	3000	10	210*210*210	4	445*445*230	120000

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