HX1610 - AGC

Wide Range Synchronous Buck Converter

Features

- ◇ Wide Input Voltage Range: 8V to 60V
- ◇ Up to 96% Efficiency
- ◇ Programmable Switching Frequency
- ◇ Programmable Current Limit
- ◇ Thermal Shutdown
- ◇ 300µA Shutdown Current
- ◇ Available in SOP-14L Package

Applications

- ◇ Automotive Systems
- ◇ Industrial Automation and Motor Control
- ◇ Electric vehicles
- ◇ Vehicle Accessories
- ◇ Tracker
- ◇ Constant power
- ◇ Solar electric equipment

Description

The HX1610-AGC is a synchronous step down regulator, operating with a wide input voltage range from 8V to 60V. The HX1610-AGC achieves up to 3.5A continuous output current with excellent load and line regulation. The switching frequency is adjustable according to the resistor value and the synchronous architecture provides for a highly efficient design. Current mode operation provides fast transient response and eases loop stabilization.

The HX1610-AGC integrates soft-start and over-temperature protection circuits, output short-circuit protection, current limit protection and other functions to improve system reliability.

The HX1610-AGC requires a minimum number of readily available standard external components. The HX1610-AGC converter is available in the industry standard SOP-14 package.

Typical Application Circuit

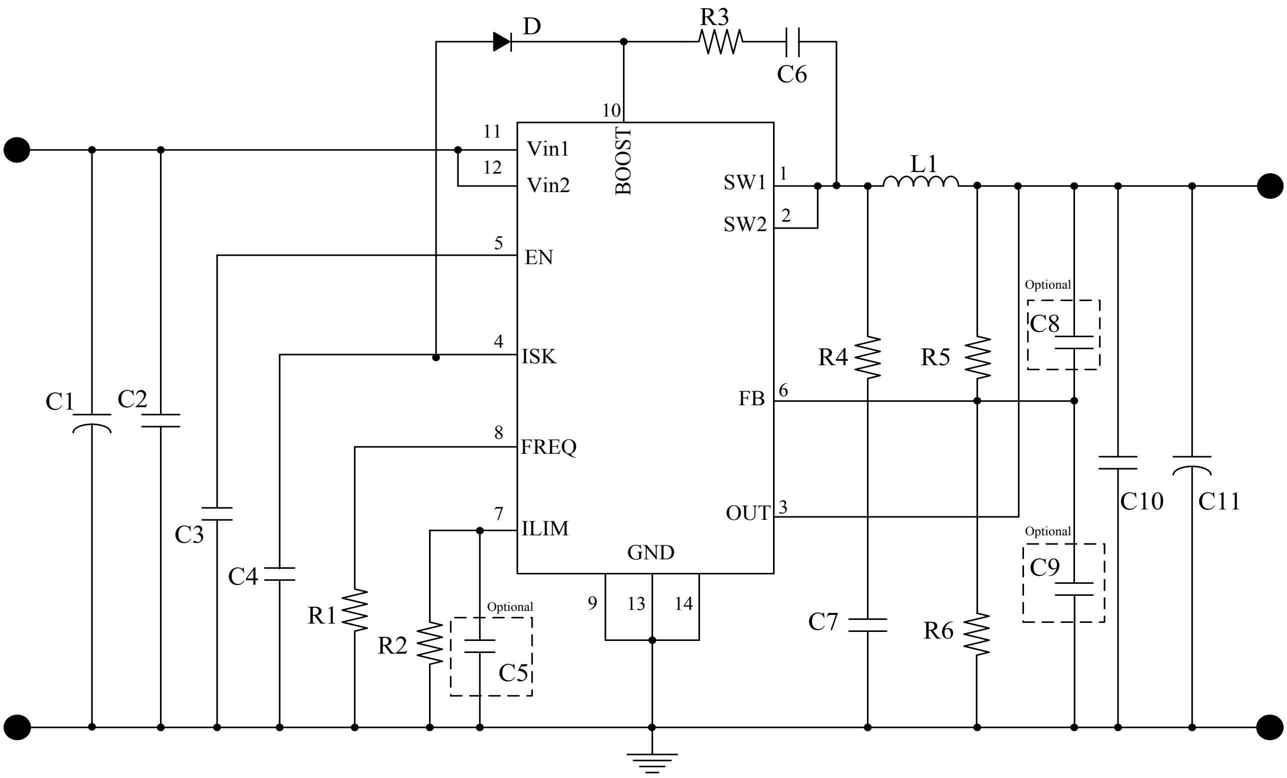
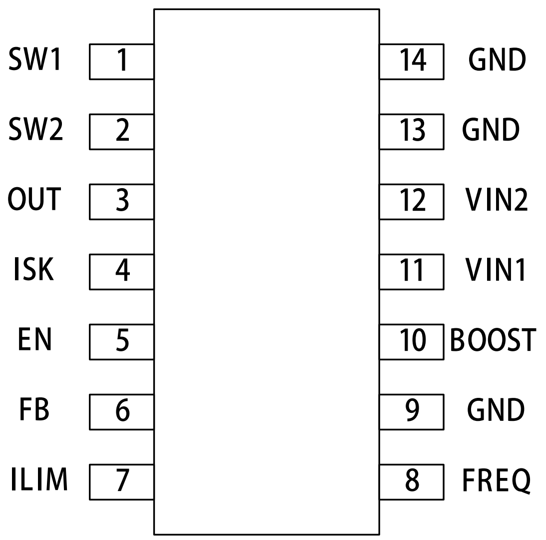


Figure 1, 8V– 60V, Synchronous Buck Converter

Pin Configuration



Absolute Maximum Ratings

Over operating free-air temperature unless otherwise noted(1).

DESCRIPTION	MIN	MAX	UNIT
VIN, EN	-0.3	65	V
BOOST	-0.3	72	V
SW	-1	65	V
ISK	-0.3	12	V
BOOST-SW	-0.3	12	V
ILIM, FREQ	-0.3	6	V
Operating junction temperature TJ(2)	-40	120	℃
Storage temperature TSTG	-65	150	℃

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

(2) The IC includes over temperature protection to protect the device during overload conditions. Junction temperature will exceed 120 ℃ when over temperature protection is active. Continuous operation above the specified maximum operating above the specified maximum operating junction temperature will reduce lifetime.

Pin Functions

NAME	NO.	PIN FUNCTION
SW	1,2	Regulator switching output. Connect SW to an external power inductor.
OUT	3	Output voltage pin.
ISK	4	Internal LDO output.
EN	5	EN Control Input. The external applied voltage need to be above 4.25V to enable the chip. The voltage need to be below 0.3V to disable the chip. When the EN pin connected with a capacitor, the EN pin voltage ranges from 4 - 5V under normal working condition.
FB	6	Feedback Pin. Receive the feedback voltage from an external resistive divider across the output. . The Output voltage is set by R5 and R6: $V_{OUT} = V_{REF} \bullet [1 + (R5/R6)]$.
ILIM	7	Tie an external resistor between this pin and ground to set max output current. The maximum output current is set by R_{LIM}: R_{LIM} (kΩ) =32.5• IMAX (A).
FREQ	8	Tie an external resistor between this pin and ground to set the operation frequency. The frequency is set by R1: R1(kΩ)=20900/f_{osc} (kHz).
GND	9, 13,14	Ground pin.
BOOST	10	Bootstrap pin. Bootstrap capacitor is charged when SW voltage is low.
VIN	11,12	Main power supply Pin. Connect a local bypass capacitor from VIN pin to GND pin. Path from VIN pin to high frequency bypass capacitor and GND must be as short as possible.

Recommended Operating Conditions

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
V_{IN}	Input Voltage Range	8		60	V
V_{OUT}	Adjustable Output Voltage Range	4.5		15	V
T_J	Operating Junction Temperature	-40		+120	℃
T	Storage Temperature Range	-65		+150	℃

Recommended Component Selection

Part Reference	C1	C2	C3	C4	C6	C7	C10	C11
Value	100µF	1µF	0.22µF	1µF	0.1µF	470pF	0.1µF	470µF
Part Reference	R2	R3	R4	R5	R6	D	L1	
Value	115KΩ	20R	5R1	100KΩ	11KΩ	4148	47µH	

Electrical Characteristics

Operating Conditions: T_A=25℃, C_{IN}=100µF, C_{OUT}=470µF, L=47µH, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input Voltage Range		8		60	V
V_{FB}	Regulated Voltage		1.17	1.2	1.23	V
V_{ISK}	Internal LDO Output Voltage Range		5		11	V
V_{IN_UVLO}	Input UVLO Threshold	V_{IN} rising		5.5		V
I_{SHDN}	Shutdown Current	EN=0V		300		µA
I_Q	Quiescent Current	I_{LOAD}=0A,V_{IN}=24V, R_{ILIM}=130K		1.52		mA
$V_{RIPPLE(P-P)}$	Output Ripple	V_{IN}=30V,I_{OUT}=2.5A		200		mV
I_{LIM}	Limit current	R_{ILIM}=115K		3.8		A
R_{DSON-H}	High-side MOSFET on-resistance	V_{BOOST} — V_{SW}=10V		68		mΩ
R_{DSON-L}	Low-side MOSFET on-resistance	V_{BOOST} — V_{SW}=10V		24		mΩ
EFFI	Efficiency	V_{IN}=20V, I_{OUT}=2.5A		96.6		%
f_{OSC}	Switching Frequency	8V < V_{IN} < 60V, FREQ pin float		80		kHz
f_{OSC}	Switching Frequency	8V < V_{IN} < 60V, R_{FREQ}=200kΩ		105		kHz
T_{SD}	Thermal Shutdown Temperature			160		℃
△T_{SD}	Thermal Shutdown Hysteresis			30		℃

Typical Characteristics

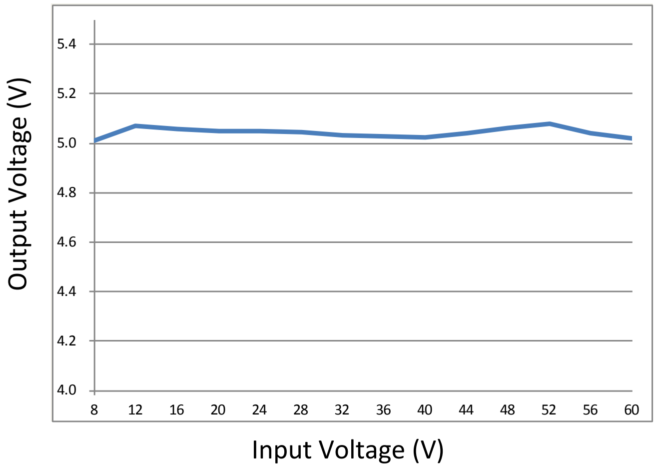


Figure 2, Input Voltage vs. Output Voltage, V_{OUT}=5V

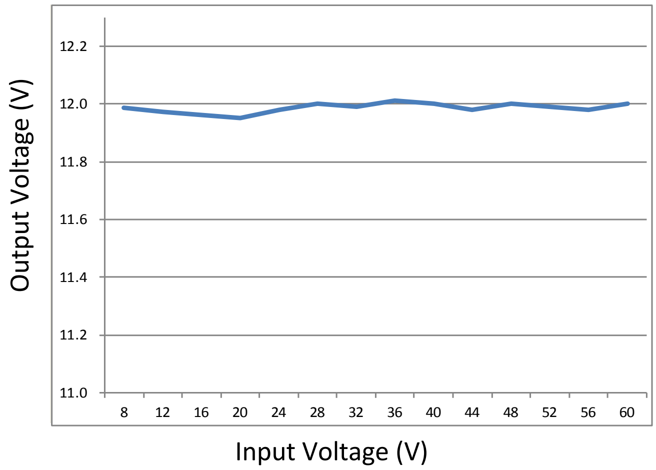


Figure 3, Input Voltage vs. Output Voltage, V_{OUT}=12V

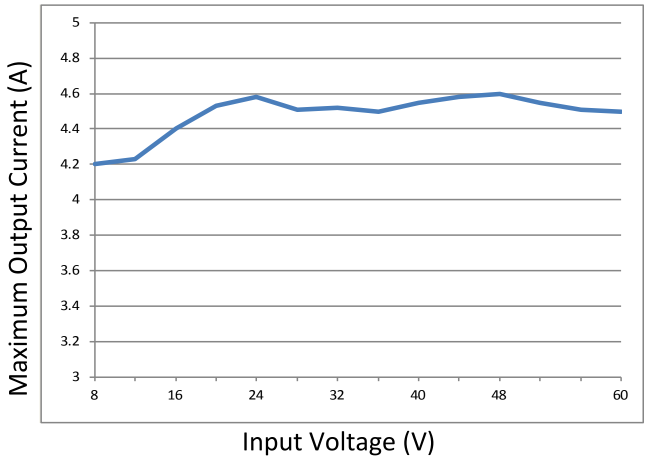


Figure 4, Input Voltage vs. Maximum Output Current, V_{OUT}=5V, R_{lim}=130k

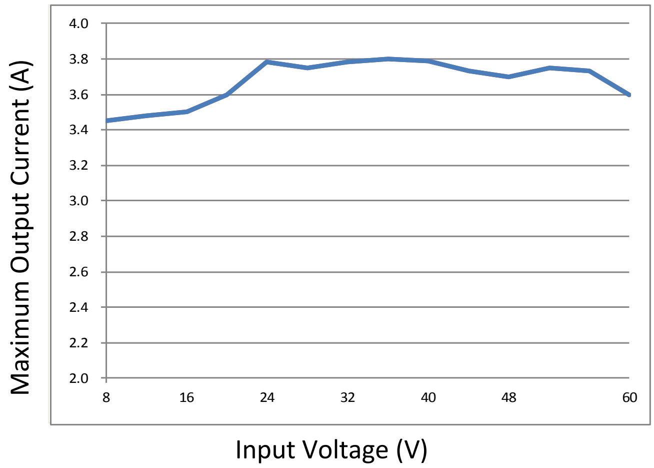


Figure 5, Input Voltage vs. Maximum Output Current, V_{OUT}=12V, R_{lim}=130k

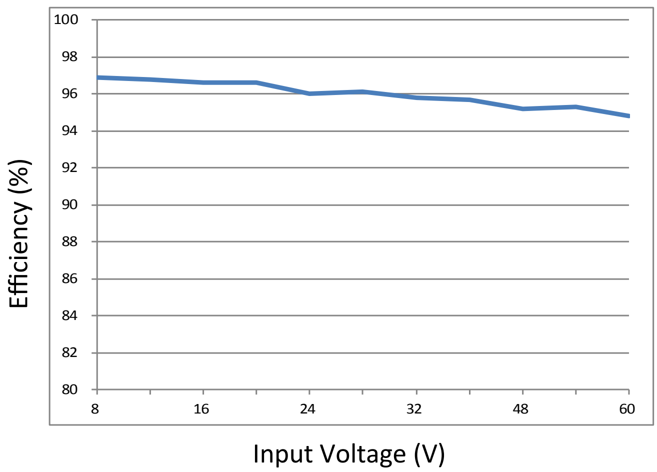


Figure 6, Input Voltage vs. Efficiency, V_{OUT}=12V, I_{OUT}=2.5A

Application Waveforms

V_{in}=30V, V_{out}=12V, unless otherwise noted.

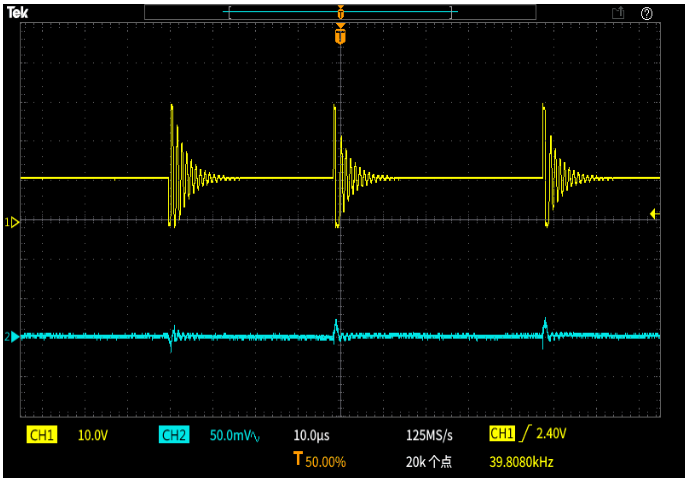


Figure 7, SW Switching & V_{out} Ripple Waveform (I_{load}=0A)

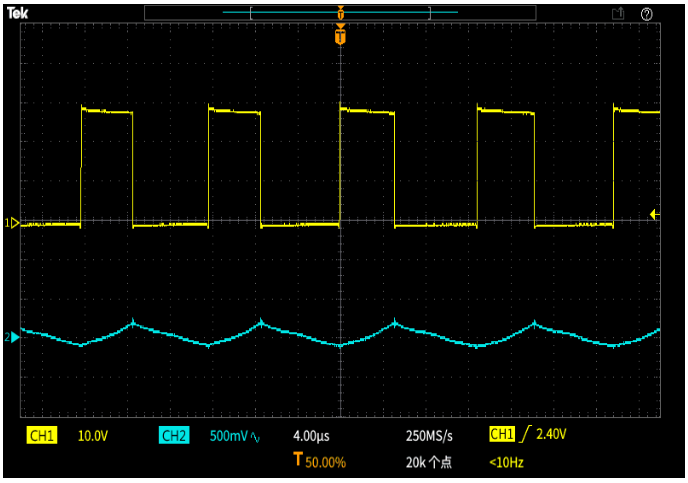


Figure 8, SW Switching & V_{out} Ripple Waveform (I_{load}=2.5A)

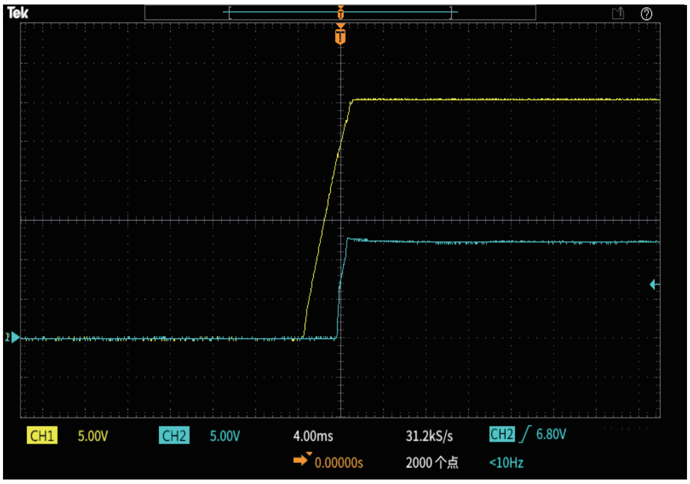


Figure 9, Power up （I_{load}=0A）

The yellow line represents VIN, the blue line represents VOUT

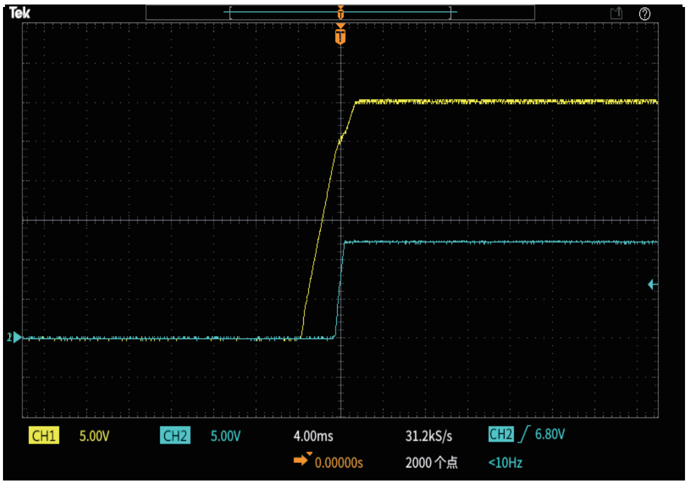


Figure 10, Power up （I_{load}=2.5A）

The yellow line represents VIN, the blue line represents VOUT

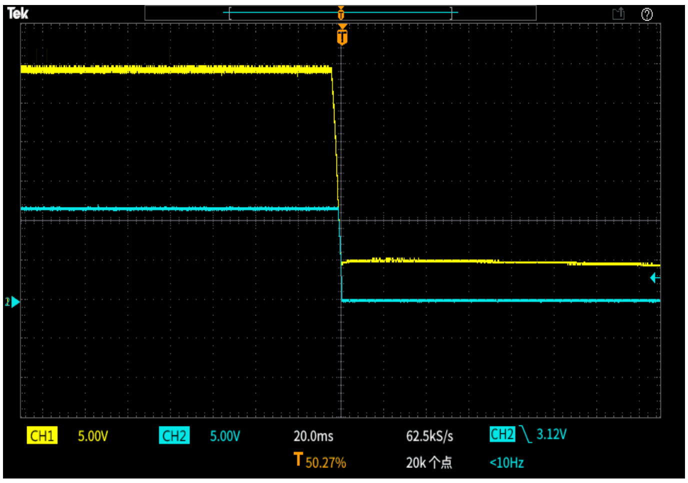


Figure 11, Power down （I_{load}=2.5A）

The yellow line represents VIN, the blue line represents VOUT

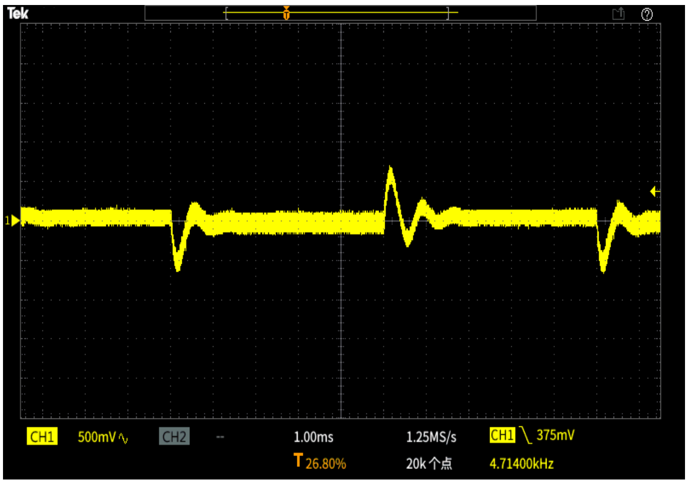


Figure 12, Load Transient （1.25A -2.5A）

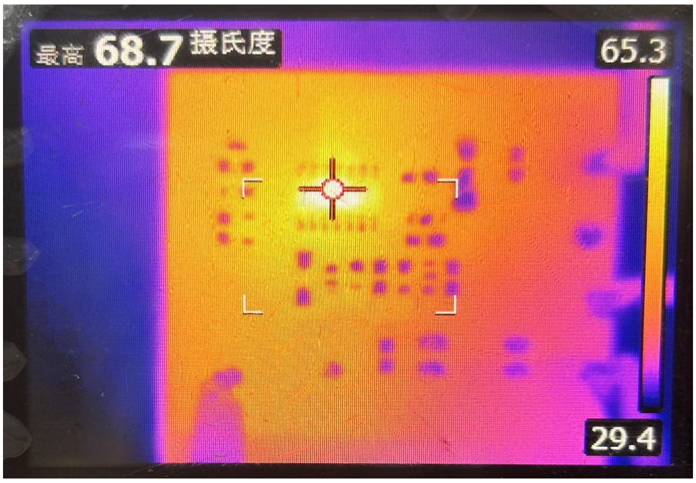


Figure 13, Thermal, $30V_{in}$, $12V_{out}$, I_{load}=2.5A

Functional Block Diagram

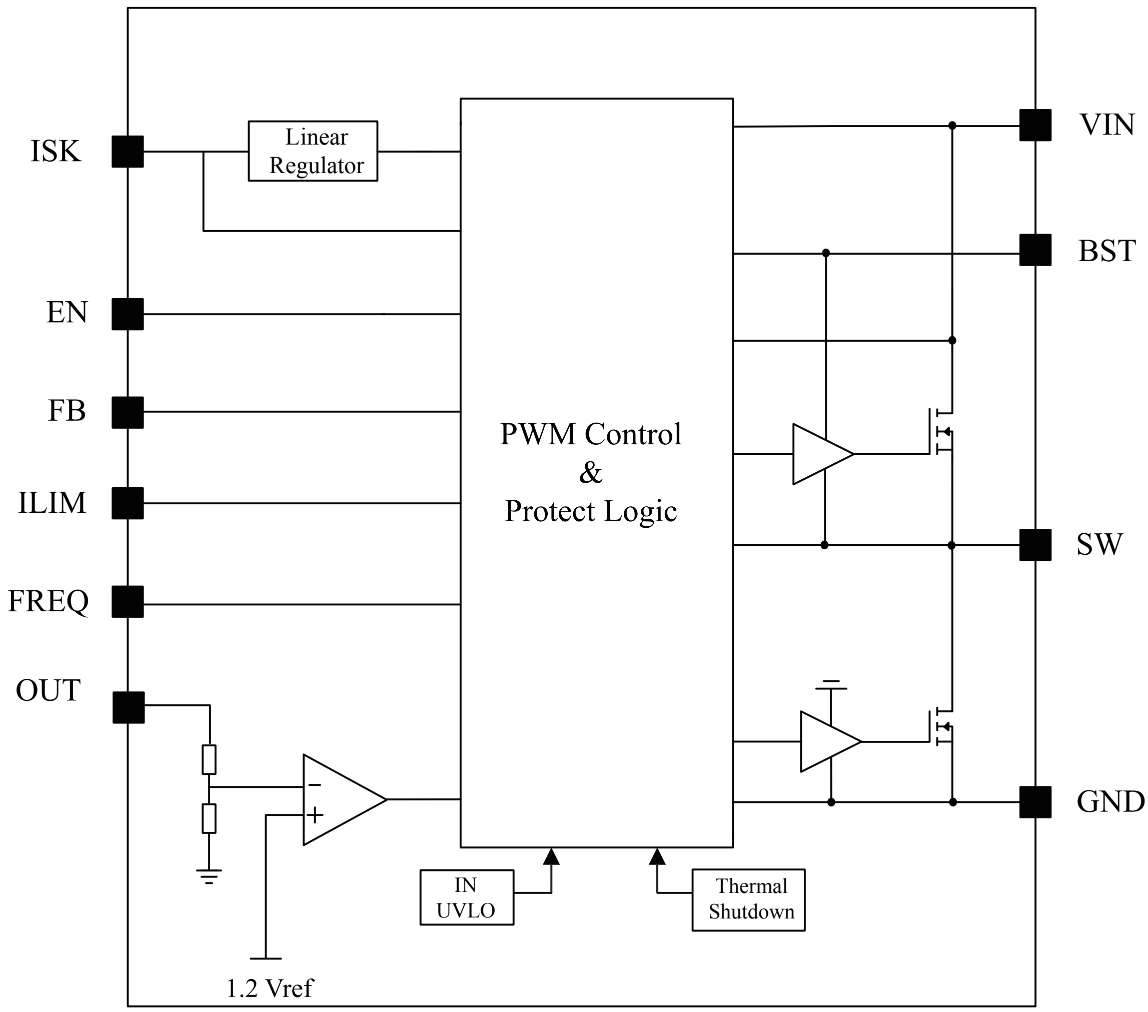


Figure 14, Functional Block Diagram

Application Information

Thermal Protection

The total power dissipation in HX1610-AGC is limited by a thermal protection circuit. When the device temperature rises to approximately 160℃, this circuit turns off the output, allowing the IC to cool. The thermal protection circuit can protect the device from being damaged by overheating in the event of fault conditions. Continuously running the HX1610-AGC into thermal shutdown degrades device reliability.

Current Limit

The current limit value is defined by R_{LIM}. The inductor Current is limited cycle by cycle defined the formula. For example, the peak current limit value is 4A by the R_{LIM} =130k. The current limit value rises when the set resistor R_{LIM} rises. The maximum output current is set by R_{LIM}: R_{LIM} (kΩ) =32.5• IMAX (A).

Oscillator Frequency

The HX1610-AGC oscillator frequency is set by a single external resistor connected between the FREQ pin and the GND pin. The resistor should be located very close to the device and connected directly to the pins of the IC (FREQ and GND). The oscillator frequency rises when there resistor R_1 decreases. To determine the resist value for a given switching frequency, use the equation below:

$$R_1(k\Omega)=20900/f_{osc}\,(kHz)$$

Setting Output Voltage

The output voltage is set by two resistors R5, R6 and the given FB pin voltage. It is recommended to use divider resistors with 1% tolerance or better. To improve efficiency at very light loads consider using large value resistors. If the values are too high the regulator is more susceptible to noise and voltage errors from the FB pin. The output voltage sets by the equation below:

$$V_{OUT} = V_{REF} \bullet [1 + (R5/R6)].$$

The chip sets the V_{REF} value to 1.2V.

Inductor Selection

For most applications, the value of the inductor will fall in the range of 47μH to 100μH. Its value is chosen based on the desired ripple current. Large value inductors result in lower ripple current and small value inductors result in higher ripple currents. Higher V_{IN} or V_{OUT} also increases the ripple current as shown in equation. A reasonable starting point for setting ripple current is $\triangle I_L$=1A (40% of 2.5A).

$$\Delta \mathbf{L} = \frac{\mathbf{1}}{(\boldsymbol{f})(\boldsymbol{L})} \boldsymbol{V_{OUT}} (\mathbf{1} - \frac{\boldsymbol{V_{OUT}}}{\boldsymbol{V_{IN}}})$$

The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation. Thus, a 3.8A rated inductor should be enough for most applications (2.8A +1A). For better efficiency, choose a low DC-resistance inductor.

Different core materials and shapes will change the size/current and price/current relationship of an inductor. Toroid or shielded pot cores in ferrite or perm alloy materials are small and don't radiate much energy, but generally cost more than powdered iron core inductors with similar electrical characteristics. The choice of which style inductor to use often depends more on the price vs. size requirements and any radiated field/EMI requirements than on what the HX1610-AGC requires to operate.

Output and Input Capacitor Selection

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle V_{OUT}/V_{IN}. To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$C_{IN}\text{required } I_{RMS} = I_{QMAX}\frac{[V_{OUT}(V_{IN} - V_{OUT})]^{\frac{1}{2}}}{V_{IN}}$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Note that the capacitor manufacturer's ripple current ratings are often based on 2000 hours of life. This makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required. Always consult the manufacturer if there is any question.

The selection of C_{OUT} is driven by the required effective series resistance (ESR). Typically, once the ESR requirement for C_{OUT} has been met, the RMS current rating generally far exceeds the $I_{RIPPLE(P-P)}$ requirement. The output ripple ΔV_{OUT} is determined by:

$$\Delta V_{OUT} = \Delta I_L(ESR + \frac{1}{8fC_{OUT}})$$

Where f = operating frequency, C_{OUT} = output capacitance and ΔI_L = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔI_L increases with input voltage.

Aluminum electrolytic and dry tantalum capacitors are both available in surface mount configurations. In the case of tantalum, it is critical that the capacitors are surge tested for use in switching power supplies. An excellent choice is the AVX TPS series of surface mount tantalum. These are specially constructed and tested for low ESR so they give the lowest ESR for a given volume.

Efficiency Considerations

The efficiency of a switching regulator is equal to the output power divided by the input power times 100%. It is often useful to analyze individual losses to determine what is limiting the efficiency and which change would produce the most improvement. Efficiency can be expressed as: Efficiency = 100% - (L1+ L2+ L3+ ...) where L1, L2, etc. are the individual losses as a percentage of input power. Although all dissipative elements in the circuit produce losses, two main sources usually account for most of the losses: VIN quiescent current and I^2R losses. The VIN quiescent current loss dominates the efficiency loss at very low load currents whereas the I^2R loss dominates the efficiency loss at medium to high load currents. In a typical efficiency plot, the efficiency curve at very low load currents can be misleading since the actual power lost is of no consequence.

1. The VIN quiescent current is due to two components: the DC bias current as given in the electrical characteristics and the internal main switch and synchronous switch gate charge currents. The gate charge current results from switching the gate capacitance of the internal power MOSFET switches. Each time the gate is switched from high to low to high again, a packet of charge ΔQ moves from VIN to ground. The resulting $\Delta Q/\Delta t$ is the current out of VIN that is typically larger than the DC bias current. In continuous mode, $I_{GATECHG} = f(Q_T+Q_B)$ where Q_T and Q_B are the gate charges of the internal top and bottom switches. Both the DC bias and gate charge losses are proportional to VIN and thus their effects will be more pronounced at higher supply voltages .
2. I^2R losses are calculated from the resistances of the internal switches, R_{SW} and external inductor R_L. In continuous mode the average output current flowing through inductor L is "chopped" between the main switch and the synchronous switch. Thus, the series resistance looking into the SW pin is a function of both top and bottom MOSFET $R_{DS(ON)}$ and the duty cycle (DC) as follows: $R_{SW} = R_{DS(ON)TOP} \times DC + R_{DS(ON)BOT} \times (1\text{-}DC)$ The $R_{DS(ON)}$ for both the top and bottom MOSFETs can be obtained from the Typical Performance Characteristics curves. Thus, to obtain I^2R losses, simply add R_{SW} to R_L and multiply the result by the square of the average output current. Other losses including C_{IN} and C_{OUT} ESR dissipative losses and inductor core losses generally account for less than 2% of the total loss.

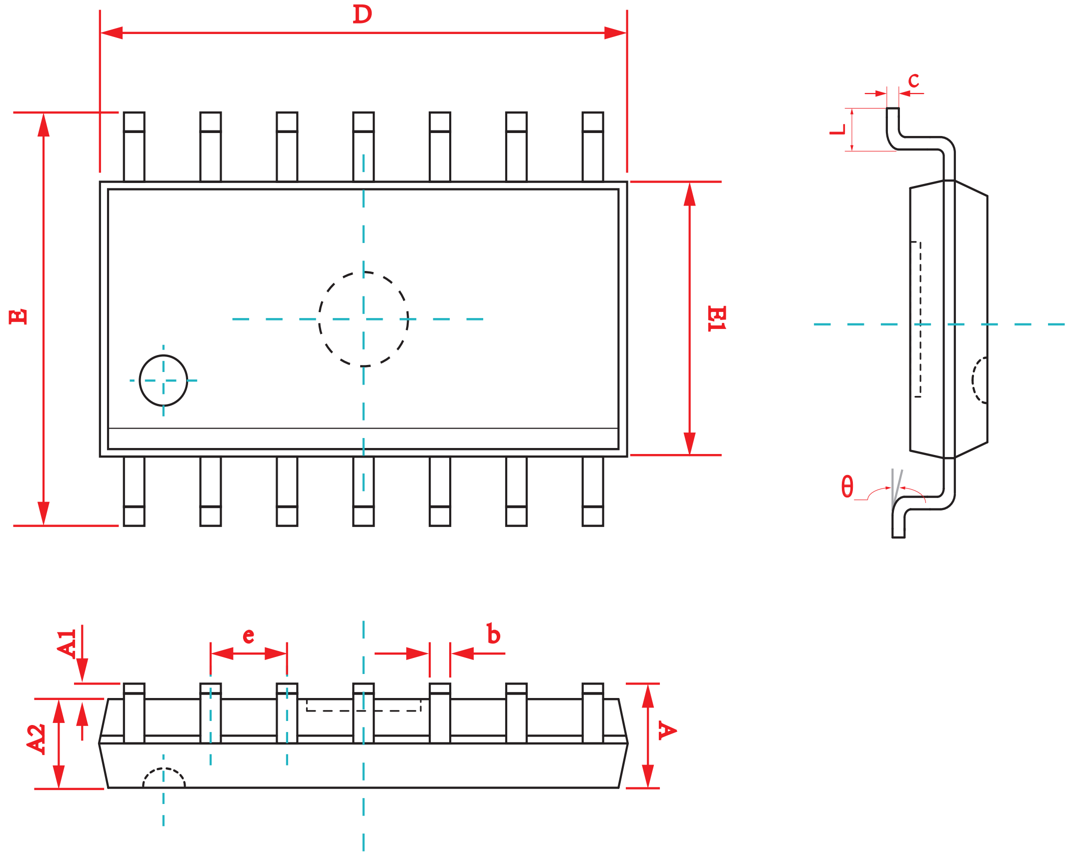
Board Layout Suggestions

When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the HX1610-AGC. Check the following in your layout.

1. The power traces, consisting of the GND trace, the SW trace and the VIN trace should be kept short, direct and wide.
2. Put the input capacitor as close as possible to the device pins (VIN and GND) .
3. SW node is with high frequency voltage swing and should be kept small area. Keep analog components away from SW node to prevent stray capacitive noise pick-up.
4. Connect all analog grounds to a command node and then connect the command node to the power ground behind the output capacitors .

Packaging Information

SOP14 Package Outline Dimension:



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	——	1.750	——	0.069
A1	0.100	0.250	0.004	0.010
A2	1.250	——	0.049	——
B	0.310	0.510	0.012	0.020
C	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
ɵ	0°	8°	0°	8°

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