GPM6954

PRIMARY SIDE REGULATOR WITH BUILT-IN HIGH VOLTAGE MOSFET

User Manual

CONTENTS

1. Overview

The GPM6954 is an offline SMPS IC with internal cable drop compensation and peak current compensation. Constant voltage/constant current (CV/CC) are available through controlling output voltage/current based on measuring primary peak current and feedback voltage of the auxiliary winding. The GPM6954 has external high-voltage triode, and it is suitable for charger, adaptor, standby power supply with output power of 8~18W. The package is DIP8.

2. Block Diagram

GPM6954 consists of UVLO, over voltage protection, peak current detection, over temperature protection, leading edge blanking, CC/CV control, open circuit protection, cycle-by-cycle current limit, and peak current compensation etc.

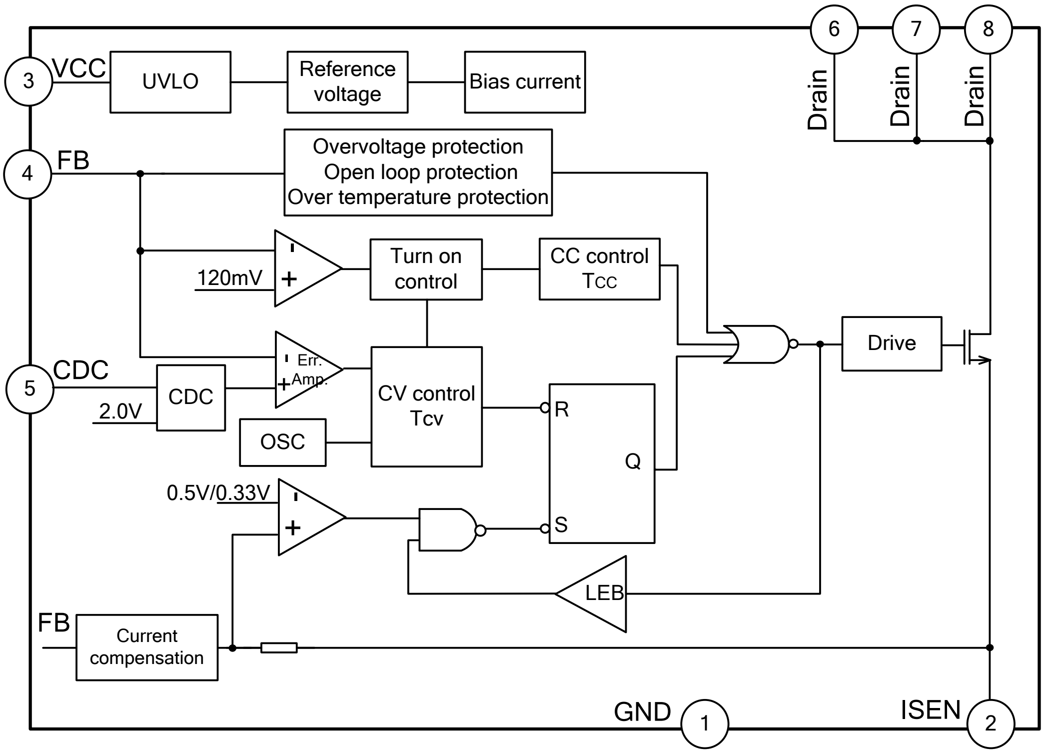


Figure 1. Block diagram of GPM6954

3. Function Description

3.1. Start-up and under voltage lockout

At the beginning of power on, the capacitor connected to pin VCC is charged via a start resistor from a high voltage DC bus and the circuit starts to work if the voltage at VCC is 16V. The circuit is powered by a start resistor and an auxiliary winding for normal operation. The whole control circuit is shutdown if VCC is decreased to 7.2V, and the capacitor connected to pin VCC is still charged through the start resistor and the IC is restarted when VCC=16V.

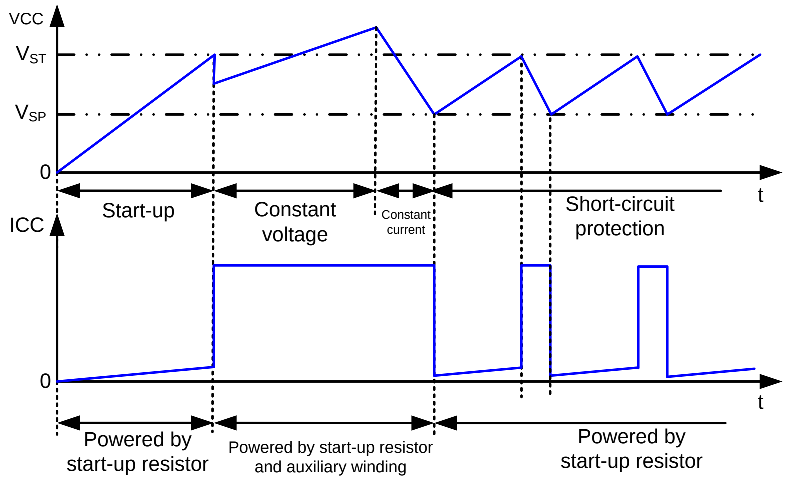


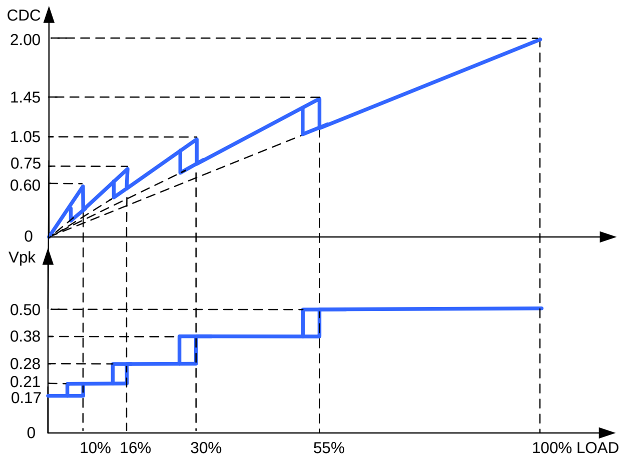
Figure 2. Start-up and voltage lockout

3.2. Peak Current Detection

When driving voltage is high, the MOSFET is on and the linearly increased primary current is detected by the sense resistor. When this current increases to the threshold value (peak value), the MOSFET is off. There is a burr when the MOSFET is on, and the MOSFET will be off by error if its voltage is up to the threshold value VPK for the peak current. So the leading edge blanking time TLEB＝0.45us is set to avoid this error.

The system load is detected according to the voltage on pin CDC. Following increases in system load:

0<CDC<0.60V, peak current threshold VPK5=170mV;
0.30<CDC<0.75V, peak current threshold VPK4=210mV;
0.40<CDC<1.05V, peak current threshold VPK3=280mV;
0.65<CDC<1.45V, peak current threshold VPK2=380mV;
1.00<CDC<2.00V, peak current threshold VPK1=500mV;



3.3. Constant Current Realization

The control circuit detects the time when V_{FB} is positive, negative or attenuated. T_{OFF1} is the time when V_{FB} is positive which means there is current delivered to the auxiliary winding; T_{ON} is the time when V_{FB} is negative which means triode is on; T_{OFF2} is the time when V_{FB} is attenuated. And during T_{ON} and T_{OFF2}, there is no current delivered to the auxiliary winding. The duty cycle of this SMPS is:

$$D_S = \frac{T_{OFF1}}{T_{OFF1} + T_{OFF2} + T_{ON}} = \frac{T_{OFF1}}{T}$$

Output current, i.e., the average current in secondary winding, is given as follows:

$$I_{OUT} = \frac{I_{SP} \cdot T_{OFF1}}{2T} = \frac{nD_S}{2} I_{PK}$$

Where, I_{SP} = peak current in secondary winding, I_{PK} = peak current in primary winding, n = turns ratio of primary/secondary windings.

So, under the condition of constant peak current, keeping D_S fixed can realize the constant current output.

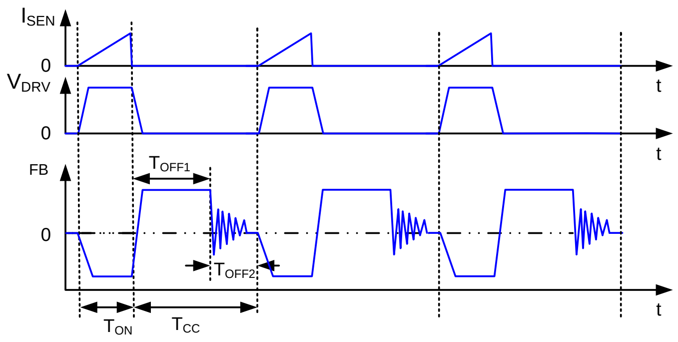


Figure 3. Constant current realization

3.4. Peak current compensation

The detected peak current value will be increased following the input AC voltage due to the off delay. And the output current is deeply affected by the peak current, hence the voltage regulation is worse without peak current compensation.

GPM6954 detects the AC input voltage through negative voltage on pin FB. The constant current source is generated based on the detected negative voltage, and it is added to ISEN, hence the peak current is kept even with different input voltage for better regulation of output current. The circuit is shown below, where the peak current compensation is built in.

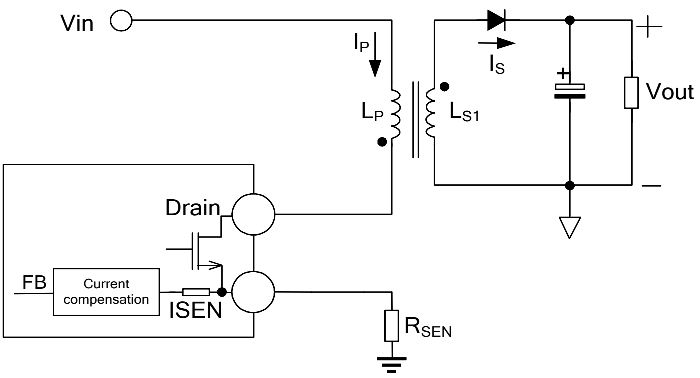


Figure 4. Circuit for peak current compensation

3.5. Cable drop compensation

In practical applications, there are different degrees of voltage drop VCAB for the output voltage on the cable.

VD can be neglected since it is almost constant with different output current, but VCAB, proportional to the output current, should be taken into consideration. To improve the load regulation of output voltage, VCV needs to be compensated properly.

According to the current calculation formula, when the peak current is constant, and the duty factor DS indicates the load of output current:

Before compensation, the duty ratio at no load is approximately 0, and VCV is 4.0V; after compensation, the duty ratio at full load is 0.5, and VCV is 4.24V, hence, the cable drop compensation coefficient is defined as 6%.

3.6. Over voltage protection

The output is shutdown if V_{FB} exceeds the threshold V_{FBOVP}=6.9V and this state is kept for 14.5ms, then the circuit restarts.

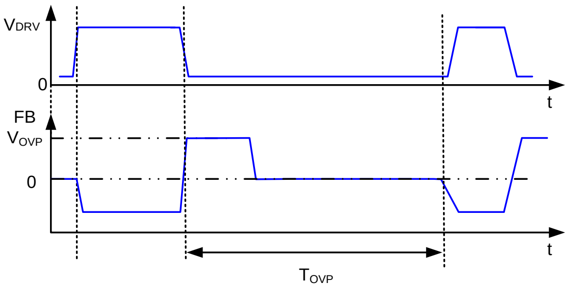


Figure 5. Over voltage protection and recovery

3.7. Open loop protection

When the MOSFET is on, if V_{FB}>－1.1V, the loop is open and open loop protection is active to shut down the output, which keeps for 14.5ms and then the circuit restarts.

4. Transformer Design

4.1. Primary/secondary turns ratio

According to Vin * D＝Vor * Ds, Vor can be calculated. In general, Vin is 90V, D is 0.42-0.45, Ds is decided by the IC, for GPM6954, Ds＝0.5. And n＝Np/Ns＝Vor/(Vo+Vf), the actual value is the integer a little lower than the value.

4.2. Primary peak current

The max. secondary output current Iomax is about 1.1 times of actual output current, and Ipk is given by:

$$1.1 * I_O = \frac{I_{pks} D_s}{2} = \frac{n I_{pk} D_s}{2}$$

Ipk is a little lower than Vcs/Rs due to the current compensation, Vcs is CS reference voltage and Rs is current sense resistance.

4.3. Primary inductance

Primary inductance is described as:

$$L_m = \frac{2P_o}{I_{pk}^2 f\eta}$$

P_o = max. output power, I_{PK} = primary peak current, f = driving frequency with full load, η = efficiency.

4.4. Primary winding turns

The effective output power of magnetic core is decided by operating frequency, max. magnetic flux density, magnetic core area, window area, and winding current density. These parameters are correlated with each other, and they are selected on the premise of minimizing the transformer size. Try to select the magnetic core, frequency and max. magnetic flux density, and then calculate the output power.

To avoid core saturation, the min. turns are described as: $N_{pmin} = \frac{L_m \times I_{pk}}{B_{sat} \times A_e}$,

Where, L_m = primary inductance, I_{PK} = primary peak current, B_{sat} = saturation flux density, the common value is 0.30T, A_e = magnetic core area. In general, Np is the integer a little larger than $\frac{L_m I_{pk}}{\Delta B \bullet A_e}$.

N_S, N_B are described below

$$nN_s = N_p$$

$$\frac{N_s}{N_B} = \frac{V_o + V_f}{Vcc}$$

4.5. Wire diameter

RMS current of primary winding:

$$I_{rms} = \sqrt{\left[\left(I_{edc}\right) + \frac{(\Delta I)^2}{12}\right] \times D_{max}}$$

Where,

$$I_{edc} = \frac{P_{in}}{V_{min} \times D_{max}}$$

$$\Delta I = \frac{V_{min} \times D_{max}}{L_m \times f}$$

RMS current of secondary winding:

$$I_{rmss} = I_{rms} \times n\sqrt{\frac{1-D_{max}}{D_{max}}}$$

Generally, current density is 5A/mm^2, and several wires connected parallel or triple insulated wire is used for the secondary winding whose current density is higher.

The performance of the transformer relates to efficiency, other specifications, and EMC. So, a good transformer should have low DC/AC power loss, low leakage inductance, low distribution capacitance, and low coupling capacitance.

4.6. Frequency Adjustment of Transformer

As the formula below,

$$P_o = \frac{1}{2} I_{pk}^2 L_m f \eta$$

I_{PK}, Po, η are fixed values, so f changes following L. That is, L is inversely proportional to the frequency.

From another point of view, Δt=L*ΔI/V. Where, ΔI equals to I_{PK} in DCM mode, V is V_{IN}, and it is constant. Hence, low L makes Δt decrease, then T_{ON} drops. As described in the formula $T_{ON}*I_{PK}*N_P=T_D*I_{PKS}*N_S$. Where, N_P, N_S are constant. So, T_D decreases following T_{ON}. Due to $D_S=T_D/T$ and D_S is fixed, decreasing of T_D results in dropping of T, then f rises.

Generally, the maximum frequency of GPM6954 is 40-50kHz for stability and high efficiency.

5. Special Element Selection

5.1. Secondary Diode Selection

Maximum input voltage Vin_max=265VAC, and the DC voltage after rectification is given:

$$Vdc\_max = Vin\_max \times 1.414 = 375Vdc$$

Margin should be considered due to voltage spike caused by leakage inductance:

$$\Delta V = 150Vdc$$

Maximum reverse voltage of diode is:

$$V_{oD}\_max = \frac{Vdc\_max + \Delta V}{n} + V_o$$

Secondary peak current is:

$$I_{pks} = \frac{2I_o}{D_s}$$

5.2. Start Resistor and Start Capacitor Selection

Start-up time and stand-by power dissipation of system are determined by start resistor and start capacitor. Lower start resistance, shorter start-up time, larger stand-by power dissipation and vice versa.

Power dissipation on the start resistor R is given by: $\frac{(V_{in} - V_{cc})^2}{R}$.

The start resistor and start capacitor should be matched for low power dissipation and short start-up time.

Figure 6 is recommended, adjust C1 to about 10 times of C2 and increase R1 to obtain the low power dissipation and short start-up time. The best result is based on the real test due to different chips.

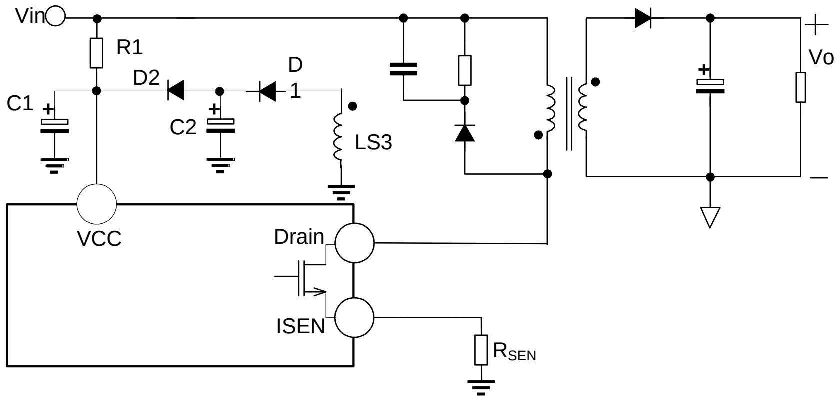


Figure 6. Start-up circuit

5.3. Output Voltage

Output voltage is decided by FB reference, R2 and R3, the schematic circuit is shown in Figure 7.

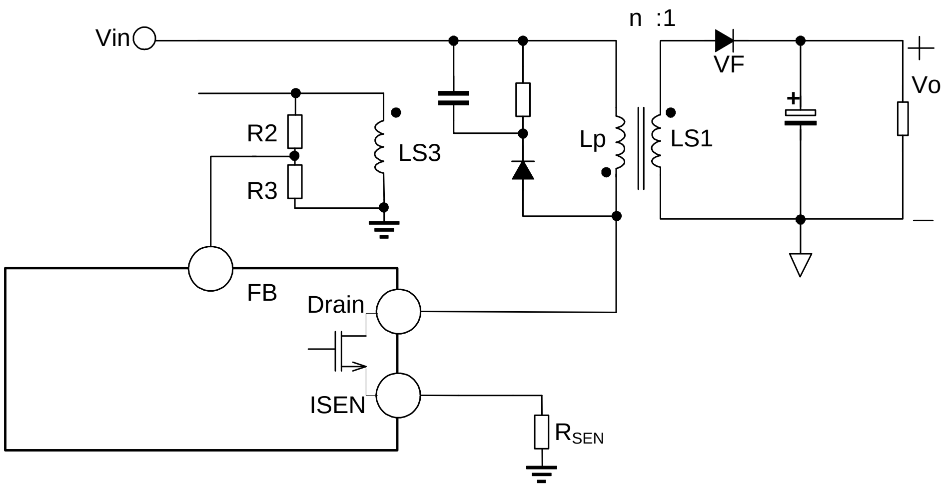


Figure 7. FB feedback circuit

In the formula $V_{S\&H} = \frac{n(V_o + V_F)R3}{R2 + R3}$, the reference voltage $V_{S\&H}$ is 4.0V, output voltage can be adjusted through R2 and R3, whose values are several KΩ.

6. Typical Application of GPM6954

6.1. Typical Application Circuit

Typical application circuit of GPM6954 12V/1A adaptor is shown in Figure 8.

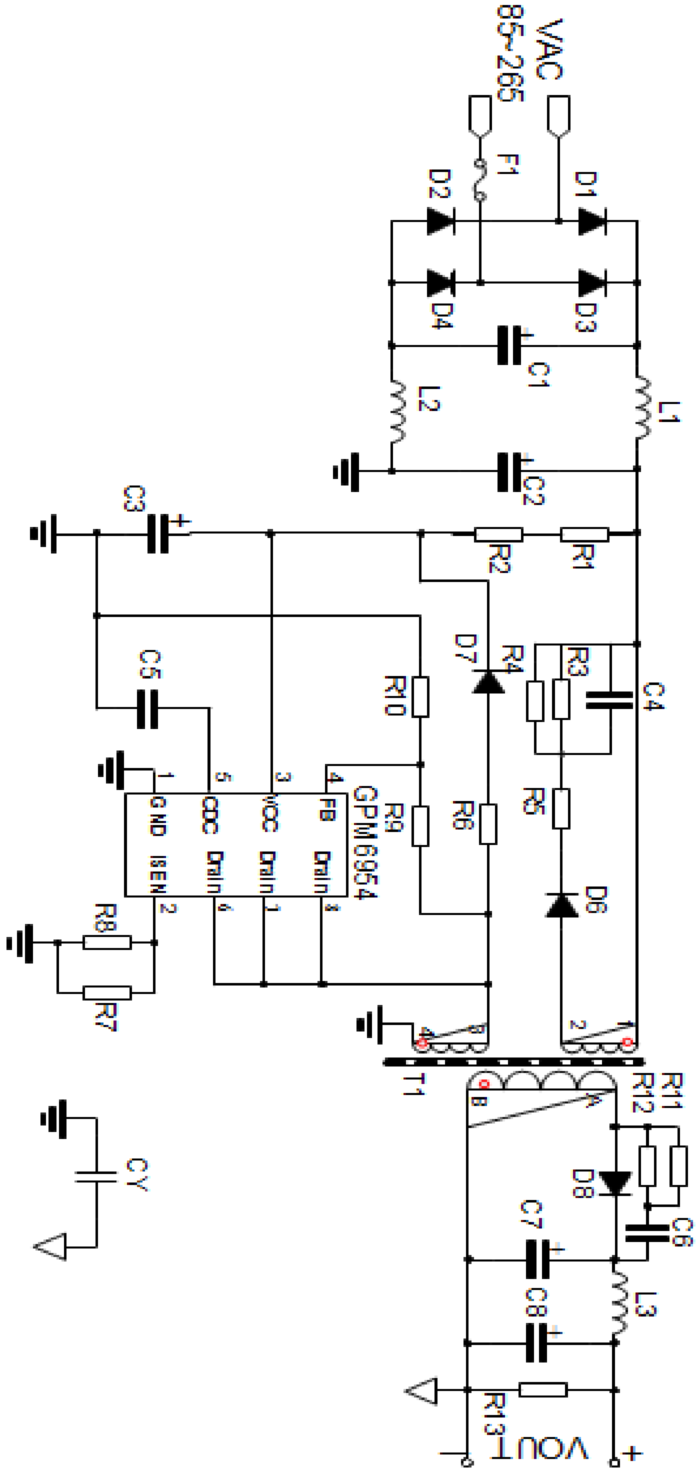


Figure 8. Typical application circuit of GPM6954 12V/1A adaptor

6.2. Bill of Material (BOM)

BOM of GPM6954 12V/1A adaptor

No.	Symbol	Qty.	Descriptions	Supplier
1	R1	1	1.5M, ±5%-0410	SEI
2	R2	1	1.5M, ±5% SMD-1206	SEI
3	R3, R4	1	330K, ±5% SMD-1206	SEI
4	R5	1	100Ω, ±5% SMD-1206	SEI
5	R6	1	3.3Ω, ±5%- SMD-1206	SEI
6	R7	1	1.0Ω, ±5%- SMD-1206	SEI
7	R8	1	1.8Ω, ±5%- SMD-1206	SEI
8	R9	1	33K, ±1%- SMD-0805	SEI
9	R10	1	12K, ±1%- SMD-0805	SEI
10	R11, R12	1	100Ω, ±5% SMD-1206	SEI
11	R13	1	3.3K, ±5% SMD-1206	SEI
12	C1, C2	2	10μF/400V, E-Cap,Φ8mmx12mm	SANCON
13	C3	1	4.7μF/50V, E-Cap	SANCON
14	C4	1	222/1KV, ±5%-SMD-1206	Panasonic
15	C5	1	474/50V, SMD-0805	Panasonic
16	C6	1	102/200V, ±5%-SMD-1206	Panasonic
17	C7、C8	1	470μF/16V, E-Cap,Φ8mmx12mm	SANCON
18	CY	1	222, Y capacitor, CAP-P10.0-ST	JEC
19	D1,2,3,4	4	IN4007, Rectifier Diode	DIODES
20	D6	1	FR107, Fast Recovery Diode	DIODES
21	D7	1	FR107, Rectifier Diode	DIODES
22	D8	1	SB3100, 100V/3A Schottky Diode	DIODES
23	L1	1	2.0mH, Inductor	N/A
24	L2	1	2.2uH, Color Ring Inductor, 0410	N/A
25	L3	1	4uH/3A, Inductor	N/A
26	U1	1	GPM6954, control chip, DIP8	**GGIC**
27	T1	1	Transformer, EF20	N/A

Note: R9 and R10 are used for adjustment of output voltage accuracy, while R7 and R8 for adjustment of max. output current.

6.3. Transformer Winding Method

Transformer structure of GPM6954 12V/1A adaptor is shown in Figure 9.

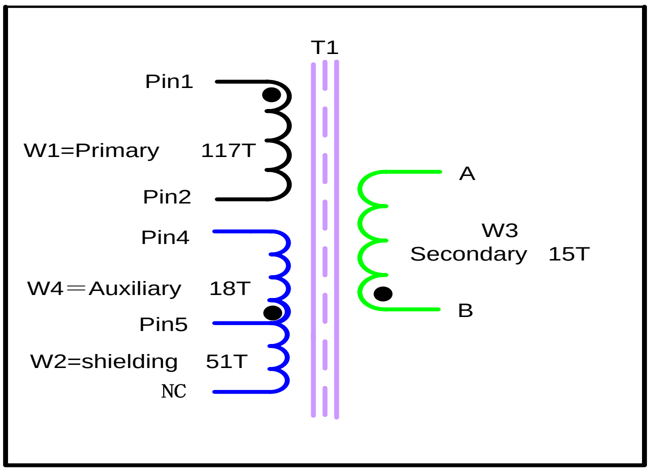


Figure 9. Transformer structure of GPM6954 12V/1A adaptor

The winding mode is shown in Figure 10.

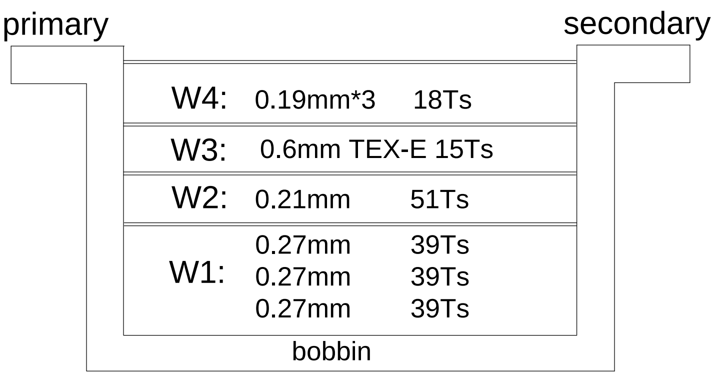


Figure 10. Transformer winding method of GPM6954 12V/1A adaptor

NO	Start	End	Wire diameter	Turns	Winding method	Insulation layers
W1	Pin 1	Pin 2	0.27mm 2UEW	117TS	Tightly winding	2
W2	Pin 5	NC	0.21mm 2UEW	51TS	Tightly winding	2
W3	B	A	0.6mm TEX-E	15TS	Tightly winding	2
W4	Pin 5	Pin 4	0.19mm*3 2UEW	18TS	Tightly winding	3

Inductance of primary winding	1.3mH±5%	Measure the inductance between pin 1 and pin 2 of primary winding with other pins floating, 10kHz, 0.4Vrms
Leakage Inductance of primary winding	＜60uH	Measure the inductance between pin 1 and pin 2 of primary winding with other pins short connected