HT45F0058 Frequency Jittering Applications

D/N : AN0563EN

Introduction

With the unceasing development of electrical and electronic technology, the electromagnetic environment is becoming increasingly complex. Countries all over the world using electronic products need to consider the issue of electromagnetic compatibility (EMC) and need to follow international standards. Some countries have formulated their own national standards and implementation schedules, and all electrical and electronic products must pass EMC-related certifications before they can be sold on the market. The relevant standards for EMI testing include GB4343.1 and EN55014-1.

When induction cookers are working at low power when the IGBT is turned on and when the IGBT working voltage is too high when the power is high, it will cause a large current and voltage, which will generate large amounts of EMI interference. A frequency jitter function is able to disperse the interference energy from a narrow frequency band into a wider frequency band without increasing the cost of the external PCB or component costs. This technique forces the original fixed operating frequency to experience periodic changes to reduce EMI interference to pass EMC related certification.

The HT45F0058 is a microcontroller especially designed for induction cookers which includes four sets of comparators, a PGA, an OVP and a 9-bit programmable pulse generator (PPG) along with other related hardware protection circuits, among which the PPG circuit contains a hardware jitter function. This function works alongside the OVP function to improve the EMI performance using frequency jitter function and the original EMC protection circuit, thereby achieving cost savings.

This application note will introduce how to use the HT45F0058 frequency jitter function to improve the EMC performance using the original EMC components.
Functional Description

EMC Introduction

Electromagnetic compatibility (EMC) means that systems operating in an electromagnetic environment will not produce electromagnetic interference that will affect the performance of other equipment operating in its surrounding environment. Therefore, EMC has two requirements. One is that devices must have a certain degree of immunity to electromagnetic interference in their environment, that is an electromagnetic resistance, EMS. The other is that during normal operation, the electromagnetic interference generated by the devices will not exceed a certain limit, this is known as EMI.

EMS test items include an electrostatic discharge test (ESD), electrical fast transient (EFT), injection current immunity test (CS), surge (impact) immunity test (Surge), voltage drop test (DIP) and Radio frequency electromagnetic field immunity (RS).

EMI test items include conducted disturbance (CE) (150kHz~30MHz), power disturbance (DP) (30MHz~300MHz) and space radiated disturbance (RE) (30MHz~1GHz / 300MHz~1GHz).

Different countries adopt different EMI regulations for home appliances. If products are to be marketed in Europe, they must pass the EN55014-1 (Electromagnetic Compatibility EMC standard emission part for household appliances, electric tools and similar appliances) standard adopted by the EU, while China adopts the GB4343.1 (Electromagnetic compatibility EMC standard emission part for household appliances, electric tools and similar appliances) standard.

EMC Component Description

Generally, common types of induction cookers where the power supply is directly connected to the rectifier circuit use the following: ferrite bead, varistor, safety capacitors and inductor EMC components, etc. Figure 1 shows an example of an EMC circuit for induction cookers. The high frequency noise at both ends of the load is filtered out and is explained below.

1. Ferrite Bead M1: When high frequency signals on the power lines pass through a ferrite bead, any high frequency noise can be converted into thermal energy in the ferrite bead. Because ferrite beads provide different resistance characteristics for different frequencies, with higher frequencies experiencing greater resistances, this forms a low-pass filter to attenuate high-frequency noise.

2. Varistor ZNR1: When the AC power supply voltage is slightly higher than the rated voltage of the varistor, the impedance of the varistor will reduce allowing part of the AC current to flow through it. The voltage across the varistor will then reduce offering protection. The impedance will afterwards return to its high impedance state to protect the circuit.

3. Safety Capacitors CX1 and CX2: In the AC circuit and rectifier circuit, these capacitors are used to filter out the instantaneous large voltage and high-frequency interference of the power supply. At the same time, they can also prevent any high-frequency interference of the load from being
fed back to the mains supply. The capacitive reactance of the noise is small, and the high-frequency noise forms a loop through the capacitor to filter the high-frequency differential mode noise. Safety capacitors cannot be replaced by general capacitors. The characteristics of safety capacitors are that they can maintain safety and have high voltage resistance after failure.

4. Inductor Coil L1: Creates a high reactance to high-frequency noise ($X_L = 2\pi f L$) and also forms a low-pass filter circuit along with the safety capacitors to suppress high-frequency noise and have a protective effect on EMS.

**Fig. 1**

**Jitter Introduction**

Frequency jittering techniques are a way to overcome the interference problems of energy being concentrated within a narrow frequency band spectrum. After widening the operating frequency, the frequency spectrum will now be distributed over a wider bandwidth, reducing the peak energy emission as shown in Figure 2. Now the total energy contained in the signal remains constant, however it is distributed over a wider frequency range. The purpose of the frequency jittering in induction cookers is to adjust the IGBT switching frequency. When it is close to the peak value of the mains at 90 degrees, the narrow band electromagnetic interference signal brought by it will reduce the IGBT $V_{CE}$ voltage and disperse the electromagnetic interference signal to reduce any EMI emissions from the induction cooker. The IGBT type can also be changed from a higher withstand voltage to lower withstand voltage type to save costs.

**Fig. 2**

**Induction Cooker Jittering Methods**

Induction cookers use changes in the PPG width to control the IGBT switching frequency and adjust the induction cooker power. However, this also generates a greater voltage differential across the IGBT $V_{CE}$, known as the reverse voltage. When the induction cooker is operating at higher power
levels, the closer it is to the envelope 90 degree phase and the more serious the EMI interference will be and the greater this reverse voltage will be. The induction cooker uses an AC zero-crossing detection circuit to trigger the timer which reduces the PPG width when the envelope phase approaches 90 degrees, and will increase the PPG width when it is far away. This will reduce the maximum reverse voltage of the envelope wave and the EMI interference created near the maximum reverse voltage. The general outline of induction cooker frequency jittering is shown in Figure 3. Here the envelope wave is divided into four sections. Interval 1 waits for the AC zero-crossing signal to start timing T1. Interval 2 is when the envelope wave approaches 90 degrees in phase, here the PPG width begins to decrease to reduce the reverse voltage. The duration of the EMI interference is the T2 time. Interval 3 is when the envelope wave is 90 degrees away from the phase, here the PPG width begins to increase to compensate for the power reduction of the induction cooker. From the end of interval 3 to the next envelope wave AC zero crossing point is interval 4. These actions are described as follows.

- t0 is the actual zero-crossing point of the envelope wave and t0’ is the zero-crossing point generated by the actual AC zero-crossing detection circuit, the timer starts timing at t0’
- t0’~t1 is the T1 time, at this time the PPG width does not change
- t1~t2 is the T2 time, at this time the PPG width will reduce, after reducing to the smallest value it will remain at this value
- t2~t3 is the T3 time, at this time the PPG width will increase, after increasing to the largest value it will remain at this value
- When t3 starts, if the power level changes, use software to modify the PPG width here
- From t0 to the next t0 time is an envelope period

There are two ways to implement a frequency jittering function. One is to use the F/W to match the relevant signals in each timing interval, to make decisions and calculations and then load the PPG settings. The other is, after setting up the relevant registers, to use the hardware to automatically calculate without software intervention and adjustment. Although using software will result in good frequency jittering flexibility and can be readily developed by users, it will be subject to the disadvantages of software execution speed and frequency jittering resolution, and will result in large software overheads. However, by using dedicated hardware to implement frequency jittering, these disadvantages can be resolved.
The HT45F0058 has an OVP circuit, which can be used as an AC zero-crossing detection circuit, a PPG frequency modulation circuit, a PPG timer, a PPG counter and a control circuit, etc., forming a dedicated hardware jittering function. The PPG width can be adjusted according to the frequency. Change the cycle to increase or decrease the PPG width. In addition, in order to make the frequency jittering process more flexible, the hardware can be set to automatically adjust the number of PPG triggers after changing the PPG width several times before changing the PPG width and also adjusting the PPG width adjustment range each time.

The dedicated hardware frequency jittering function of the HT45F0058 not only reduces software execution overheads, but also has better flexibility in adjusting the PPG width. In this application, the HT45F0058 can use hardware or software to implement a frequency jittering function, and can also choose a partial hardware method to implement frequency jittering. For example, when the OVP detects an AC zero-crossing signal, the PPG Timer can be triggered by software or use other timers as the jitter reference clock source, while the PPG width adjustment is implemented by hardware. Users must use software to determine the current timing to request the hardware to increase or decrease the PPG width. However, for hardware frequency jittering implementation, after the hardware has completed the jittering settings, when the OVP detects a AC zero-crossing signal, the PPG timer is triggered to start timing, and to determine whether the PPG width is to increase or decrease according to the current timer time. The modulation width is automatically adjusted by the hardware according to the settings, thereby reducing the burden on the software.

**Operating Principles**

**Software Setup**

**Registers**

To use the HT45F0058 PPG dedicated hardware frequency jitter function, in addition to setting the PPG related registers, the OVP and CMP registers must also be setup along with the related I/O pin sharing functions. For the related register setting instructions, the CMP register and other basic PPG-related registers, details will not be described here. For details, refer to the datasheet. Regarding the PPG dedicated hardware frequency jitter function, including the automatic adjustment of the PPG width register and envelope wave jitter timing and other related register functions, these are shown in the following table.

<table>
<thead>
<tr>
<th>Register</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVPC0</td>
<td>OVP enable, output polarity and output debounce time control</td>
</tr>
<tr>
<td>OVPC1</td>
<td>OVP input offset calibration register</td>
</tr>
<tr>
<td>OVPC2</td>
<td>OVP hysteresis voltage and OVP positive input selection control</td>
</tr>
<tr>
<td>OVPDA</td>
<td>OVP negative terminal reference voltage selection ((0V−5V)) ((V−= (5/256)×OVPDA))</td>
</tr>
<tr>
<td>PPGATC0</td>
<td>Approach mode control and approach status register</td>
</tr>
<tr>
<td>PPGATC1</td>
<td>PPG Timer Trigger source and PPG trigger approach value selection</td>
</tr>
<tr>
<td>PPGATC2</td>
<td>PPG Automatic adjustment of trigger times and approach value</td>
</tr>
<tr>
<td>PPGTMC</td>
<td>PPG Timer Setup</td>
</tr>
<tr>
<td>Register</td>
<td>Function</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>PPGTMR1</td>
<td>Envelope waveform jitter T1 timing register</td>
</tr>
<tr>
<td>PPGTMR2</td>
<td>Envelope waveform jitter T2 timing register</td>
</tr>
<tr>
<td>PPGTMR3</td>
<td>Envelope waveform jitter T3 timing register</td>
</tr>
<tr>
<td>PPGTMRD</td>
<td>PPG timing register</td>
</tr>
<tr>
<td>PPGTA</td>
<td>PPG counter preload register A</td>
</tr>
<tr>
<td>PPGTC</td>
<td>PPG counter approach register C</td>
</tr>
<tr>
<td>PPGTD</td>
<td>PPG counter approach register D</td>
</tr>
<tr>
<td>I/O</td>
<td>PxSn  I/O pin-share function setting</td>
</tr>
</tbody>
</table>

Setup Process Description

1. Initialise the PPGTA, PPGTC and PPGTD registers
   (Note: it is necessary to first write the high byte, then write the low byte, to ensure the data is accurately loaded)

2. Setup the PPGATC1 internal PPGCNT and PPGSA, determine whether the PPG width will automatically adjust after several PPG triggers

3. Setup PPGATC2, after deciding to automatically adjust the PPG width several times, automatically adjust the width value of each adjustment of PPGTA and the number of PPG triggers required for each width adjustment

4. The time from the OVP zero-crossing interrupt trigger to t1 is set to PPGTMR1; the time width from t1 to t2 is set to PPGTMR2; the time width from t2 to t3 is set to PPGTMR3. (The time relationship between t1, t2 and t3 is shown in Figure 5)

5. Setup PPGTMC to select the required frequency division ratio for fH to be the PPGTIMER timing clock source

6. Setup the other PPG related registers (Consult the Datasheet PPG chapter)

7. Setup the OVP related registers (Consult the Datasheet OVP chapter)

Fig. 4

Step 1: Initialise the PPGTA, PPGTC and PPGTD registers

Step 2: Setup the PPGATC1 internal PPGCNT and PPGSA, determine whether the PPG width will automatically adjust after several PPG triggers

Step 3: Setup PPGATC2, after deciding to automatically adjust the PPG width several times, automatically adjust the width value of each adjustment of PPGTA and the number of PPG triggers required for each width adjustment

Step 4: The time from the OVP zero-crossing interrupt trigger to t1 is set to PPGTMR1; the time width from t1 to t2 is set to PPGTMR2; the time width from t2 to t3 is set to PPGTMR3. (The time relationship between t1, t2 and t3 is shown in Figure 5)

Step 5: Setup PPGTMC to select the required frequency division ratio for fH to be the PPGTIMER timing clock source

Step 6: Setup the other PPG related registers (Consult the Datasheet PPG chapter)

Step 7: Setup the OVP related registers (Consult the Datasheet OVP chapter)
Step 8: Setup the CMP related registers (Consult the Datasheet CMP chapter)

Step 9: Set PPGSAMD=1 (H/W approach mode). When PPGSAMD changes from 0 to 1, PPGTON will be cleared to 0, before this bit is 1, ensure that other related settings have been completed to avoid unexpected errors.

During frequency jittering, PPGACF and PPGADF can be read to determine whether PPGTA is equal to PPGTC or PPGTD and PPGTMMD[1:0] can be read to determine the PPGTIMER current working mode. In addition, in the dedicated hardware jitter frequency setting, in addition to Comparator 0 (synchronous circuit comparator) and the OVP zero-crossing detection comparator, the setting must be completed first as well as the Comparator 1 (LC parallel resonant reverse-voltage protection comparator) setting. It is necessary to ensure that C1VOD is 1 and RLBF is 0, otherwise the PPG frequency jitter change cannot be seen in the PPG output width. When C1VOD is 0, this means that the IGBT VCE has exceeded the set value and PPGDEB[3:0]=0. At this time, the system does not perform frequency jittering but reduces the PPG width. If RLBF is 1, the PPG output width is loaded by PPGTB instead of PPGTA.

After the dedicated hardware frequency jittering, the other comparators and PPG functions have been setup, when PPGSAMD=1 and PPGHTMD=0 as shown in Figure 5, when the OVP detects an AC zero signal, the PPGTIMER will be triggered to start the T1 timing. At this time the PPG output remains unchanged. The PPGTA will approach PPGTC during the T2 time. During the T3 timing, PPGTA will approach PPGTD. After the T3 timing has completed, PPGTA can be reassigned by software until the next OVP trigger signal has completed a cycle. It should be noted that PPGTA, PPGCNT and PPGSA cannot be assigned by software during the period from t1 to t3.
Application Example

The following table shows an application example for setting up the frequency jittering registers for an induction cooker.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPGTC</td>
<td>PPGTA+50</td>
<td>PPG initial width - ( (50/f_{SYS}) ) µs ( (f_{PPGDCK}/f_{SYS}) )</td>
</tr>
<tr>
<td>PPGTA</td>
<td></td>
<td>PPG initial width</td>
</tr>
<tr>
<td>PPGATC0</td>
<td>0x40</td>
<td>PPGTA approach mode ---H/W approach mode</td>
</tr>
<tr>
<td>PPGATC1</td>
<td>0x00</td>
<td>PPG Timer trigger source select OVP interrupt signal (OVPINT), each PPG trigger, PPGTA ± 1</td>
</tr>
<tr>
<td>PPGATC2</td>
<td>0x00</td>
<td>PPG trigger number and PPGTA approach value does not change with the PPGTA number of changes.</td>
</tr>
<tr>
<td>PPGTMR1</td>
<td>255</td>
<td>Operating interval ( T_1 = (256-255) \times 32)µs = 0.032ms</td>
</tr>
<tr>
<td>PPGTMR2</td>
<td>166</td>
<td>Operating interval ( T_2 = (256-166) \times 32)µs = 2.880ms</td>
</tr>
<tr>
<td>PPGTMR3</td>
<td>181</td>
<td>Operating interval ( T_3 = (256-181) \times 32)µs = 2.400ms</td>
</tr>
<tr>
<td>PPGTMC</td>
<td>0x02</td>
<td>PPGTIMER OVPINT triggers source select rising source; PPGTimer CLK = ( f_H/512 = 32)µs ( (f_H=16MHz) )</td>
</tr>
</tbody>
</table>

Example Code (C Source)

```c
void PPG Shake Frequency_init( )
{
    if(_ppgta8==1)
    {
        _ppgtc8 = 1;
        _ppgc = _ppgta+50;
        _ppgd0 = 1;
        _ppgd = _ppgta;
    } 
    else 
    {
        _ppgtc8 = 0;
        _ppgc = _ppgta+50;
        _ppgd0 = 0;
        _ppgd= _ppgta;
    } 
    _ppgatc1 = 0x00;
    _ppgatc2 = 0x00;
    _ppgtmr1 = 256-1;
    _ppgtmr2 = 256-90;
    _ppgtmr3 = 256-75;
    _ppgtmc = 0x02;
    _ppgatc0 = 0x40;
}
```
Test Waveforms

<table>
<thead>
<tr>
<th>No Jittering</th>
<th>With Jittering</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Waveform" /></td>
<td><img src="image2.png" alt="Waveform" /></td>
</tr>
<tr>
<td>IGBT $V_{CE}$ Voltage (Max.) = 1300V</td>
<td>IGBT $V_{CE}$ Voltage (Max.) = 1250V</td>
</tr>
</tbody>
</table>

Yellow Waveform (CH1) $\rightarrow$ IGBT $V_{GE}$ Waveform
Green Waveform (CH4) $\rightarrow$ IGBT $V_{CE}$ Waveform (Induction Cooker LC parallel resonance reverse voltage)
Red Waveform (CH M) $\rightarrow$ IGBT $V_{GE}$ (Positive pulse width line (PPG output width line))

Test results: The IGBT voltage when using frequency jittering can be reduced by about 50V when compared with the IGBT voltage without frequency jittering.

Test Data

The following EMI test data is based on the test results when the induction cooker is operating with a power level of 2000W. The EMC components have a higher specifications but without frequency jitter, they are compared with lower specification EMC components but with frequency jitter.

Reference Circuit – Power Supply

![Reference Circuit](image3.png)

Test Data

- CE Data
  - The test results without frequency jittering for $CX_1=8\mu F$ and $CX_1=5\mu F$: When $CX_1$ is 8$\mu F$ there is a minimum average margin of 5.98dB. With $5\mu F$ there is a minimum average margin of 5.20dB. The larger capacitance safety capacitor has a better EMI margin, about 0.78 dB.
The test results for CX1=8µF without frequency jittering and CX1=5µF with frequency jitter show that using frequency jitter is better. The minimum margin is increased by 0.89dB compared with the condition without frequency jitter and where a larger capacitance value is used.

Whether CX1=8µF or CX1=5µF without frequency jittering or CX1=5µF with frequency jittering, the DP test results are not much different, and the average margin is above 10dB.
The following table shows the difference in frequency jitter to EMI and component cost comparison and also shows the CE and DP test results. If there is no frequency jitter, larger safety capacitors have better results for EMI CE, but when using a lower cost 5µF safety capacitor with frequency jitter, the CE margin is higher.

### Frequency Jitter to EMI difference and component cost comparison

<table>
<thead>
<tr>
<th>Component</th>
<th>Condition</th>
<th>CX1=8µF/No Jittering</th>
<th>CX1=5µF/No Jittering</th>
<th>CX1=5µF/With Jittering</th>
</tr>
</thead>
<tbody>
<tr>
<td>CX1</td>
<td>8µF/275VAC+(1.8RMB)</td>
<td>5µF/275VAC-(0.8RMB)</td>
<td>5µF/275VAC-(0.8RMB)</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td></td>
</tr>
<tr>
<td>CX2</td>
<td>5µF/275VAC-(0.8RMB)</td>
<td>5µF/275VAC-(0.8RMB)</td>
<td>5µF/275VAC-(0.8RMB)</td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>300µH-(3.0RMB)</td>
<td>300µH-(3.0RMB)</td>
<td>300µH-(3.0RMB)</td>
<td></td>
</tr>
<tr>
<td>Conducted Interference CE(2000W)</td>
<td>PASS(+5.98dB)</td>
<td>PASS(+5.20dB)</td>
<td>PASS(+6.87dB)</td>
<td></td>
</tr>
<tr>
<td>Power Interference DP(2000W)</td>
<td>PASS(&gt;10dB)</td>
<td>PASS(&gt;10dB)</td>
<td>PASS(&gt;10dB)</td>
<td></td>
</tr>
<tr>
<td>EMC Component Cost (RMB)</td>
<td>5.6</td>
<td>4.6</td>
<td>4.6</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: The conducted interference margin +x dB represents the minimum margin x dB, -x dB represents the limit exceeding the maximum x dB; power disturbance > 10dB, means the minimum margin is greater than 10dB, the test software does not detect important points, and the margin is large with no calibration.

Note 2: These results originate from the Holtek laboratory. The test regulations adopted are the EU certification EN55014-1. There may be 1~2dB difference in test results between different laboratories and the test result margin is greater than 3dB to reach the EMI test safety range.

Note 3: The above costs are for reference only.

### Conclusion

This application note has shown how the HT45F0058 frequency jittering function can reduce the cost of additional EMC components. In addition to explaining the function and usage of the dedicated hardware frequency jittering function, in the test experiment the voltage across the IGBT $V_{CE}$ can be reduced to 50V by using frequency jittering, allowing EMC components with lower voltage ratings to be used. Frequency jittering makes a better difference to EMI when compared with EMC higher specified components.
Reference Material

Consult the HT45F0058 Datasheet.

For more information see the Holtek website: www.holtek.com.

Revision Information

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<th>Author</th>
<th>Issue Release</th>
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<td>陳世諭 Rekkles</td>
<td>V1.00</td>
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