Programmable PLL Impact on EMC Behavior

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***Abstract*— This paper discuss the electromagnetic compatibility (EMC) effect of a programmable phase-locked loop (PLL). The international electrotechnical commission (IEC) 61967-2 measurement standard [1] is followed to measure the electromagnetic interference (EMI) by TEM-CELL. Comparisons are done among EMI behaviors and different PLL settings of the same functionality. Different measurements are done to confirm the stability and repeatability. Generally, the measurements and observations are reasonable across the bandwidth — the higher the PLL frequency the higher EMI. However, at some frequencies, the phenomena are reversed. Thus, it is possible to control PLL by program to change the behavior of EMI and reduce EMI at specific frequencies by software which may save the hardware cost.**

Key words: EMC, PLL, IEC, EMI, programmable PLL

I. INTRODUCTION

Technology and market trends leads to smaller feature sizes and demands much more functions in one product which causes higher system clock frequencies and more transistor count in one die. As the system being more functions, faster, and smaller, the simultaneous switching noise (SSN) caused by integrated circuit (IC) components can not be neglected. EMC problems of these systems are inevitably getting more attentions.

Our lab studied to the program impact on EMC behavior. In previous researches [2]–[5], it is confirmed that micro-controller has different EMI behaviors with different instruction and execution sequence on the same system.

There are researches for PLL impact on EMI, for example, Demoor [6] compared the EMI of three different PLL devices; Michel and Neron [7] used hardware to control the PLL frequency. However, seldom focus on the EMI behavior affected by a program controllable PLL.

This paper will discuss the programmable PLL impact on EMC behavior of a micro-controller. The Microchip PIC24HJ12GP202 controller [8] is used in this paper. The micro-controller includes a programmable PLL which will be detailed later. The EMI behaviors of the micro-controller are measured. The measurements are done by TEM-CELL according to IEC61967-2 standard. We use program to control the PLL behavior and compare the EMI behaviors for different PLL settings of the same functionality. By controlling the PLL, the EMI behavior is changed and may improve EMI behavior through software and save the hardware EMI reduction cost.

II. PCB DESIGN AND MEASUREMENT

A. PCB design

The design under test (DUT) is a 16 bit programmable PLL PIC controller. IEC61967-2 is followed to design a 10 cm × 10 cm four layers FR4 test board (Fig. 1 and Fig. 2). The test board has one LED and five ports. The DUT is driven by a 10 MHz external crystal oscillator. Different programs are designed to control the PLL frequency.

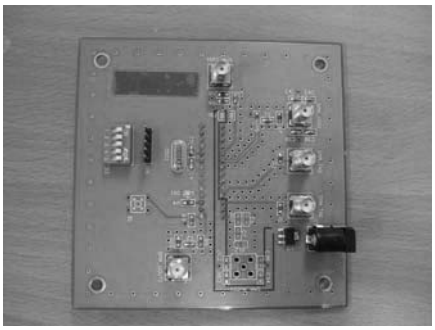

Fig. 1 Test board (bottom)

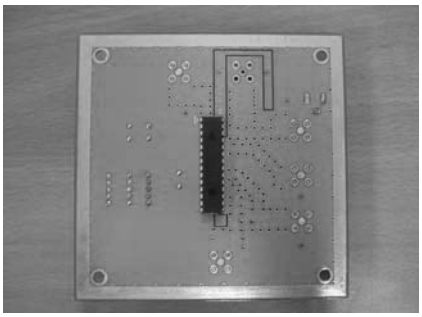

Fig. 2 Test board (top)

B. TEM-CELL measure

We follow IEC61967-2 to design and measure the target. According to the standard, the measurement takes two directions and finds the maximum EMI measured: 0° and 90° orientations (Fig. 3). RBW is set 3 KHz (150 KHz to 1 MHz) and 10 KHz (1 MHz to 1GHz). Two measurement

environments and setups are used to verify the measurement stability and repeatability. First environment is in the Bureau of Standards, Metrology and Inspection (BSMI), Taiwan and use the FCC TEM-CELL [9] (Fig. 4a). Second environment is in Feng Chia University (FCU) and use the TEM-CELL is designed by FCU [10] (Fig. 4b).

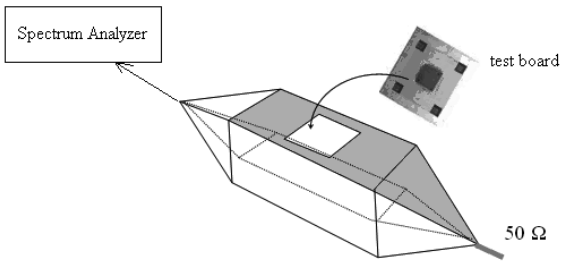

Fig. 3 TEM-CELL measurement

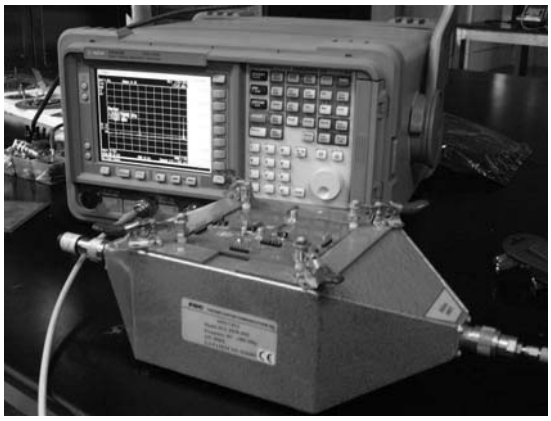

Fig. 4a Measure environment in BSMI

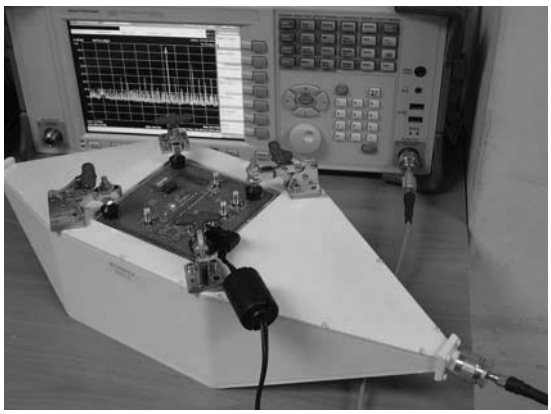

Fig. 4b Measure environment in FCU

III. MEASURE PROGRAM DESIGN

We use Microchip MPLAB IDE [11] and MPLAB IDE2 programmer to download different PLL settings and maintain the same software functionality into the PIC controller.

A. Programmable PLL settings

IC24HJ12GP202 can dynamically set register values to control PLL on/off and its frequency by program (Fig. 5). The testing programs will set PLL on/off, 1X (10 MHz), and 8X (80 MHz) on the same functionality (the IO output LED flashes in 1 Hz frequency) to compare different PLL settings impact on EMI.

```
START:                                  ;PLL 10M
        MOV #0x0006,W1
        MOV W1,PLLFBD
        NOP
        MOV #0x3040,W2
        MOV W2,CLKDIV
        NOP
```

Fig. 5a PLL set register program (PLL = 1X)

```
START:                                  ;PLL 80M
        MOV #0x3E,W1
        MOV W1,PLLFBD
        NOP
        MOV #0x3040,W2
        MOV W2,CLKDIV
        NOP
```

Fig. 5b PLL set register program (PLL = 8X)

PLL frequency set equation:

$$F_{OSC} = F_{IN} \times \left(\frac{M}{N_1 \times N_2} \right) \quad (1)$$

The N1, N2, and M are registers to control PLL frequency. When the program sets M = 8, N1 = 4, N2 = 2, the PLL output is set to 1X (internal clock frequency is 10 MHz, Fig. 5a). When the program sets M = 64, N1 = 4, N2 = 2, the PLL output is set to 8X (internal clock frequency is 80 MHz, Fig. 5b). Different delay-loop adjustments are made to ensure the LED flash frequency remains in 1Hz; other functions remain the same under different PLL settings.

IV. MEASURE RESULT

Testing board is measured under different PLL settings BSMI and FCU environment to verify the measurement stability and repeatability.

A. Different environment measurement verification

We use TEM-CELL measurement that follows the IEC61967-2 in both FCC and FCU measure environments.

The FCC TEM-CELL measure environment uses Agilent E7405A without pre-amplifier (preAmp), the noise floor is high. While in FCU TEM-CELL measure environment, we use Spectrum Analyzer's (Agilent N1996A) with internal preamp. The waveforms measured form FCC are also observed in FCU and the peak differences are under 6 dBμV (Fig. 6 – Fig. 8). Since the FCU measurement environment has preAmp, the noise floor is lower and more details can be observed.

From Fig. 6 – Fig. 8 the measurement variations between BSMI and FCU are small enough. The FCU measure results are reliable. We proceed to the measurement only in FCU.

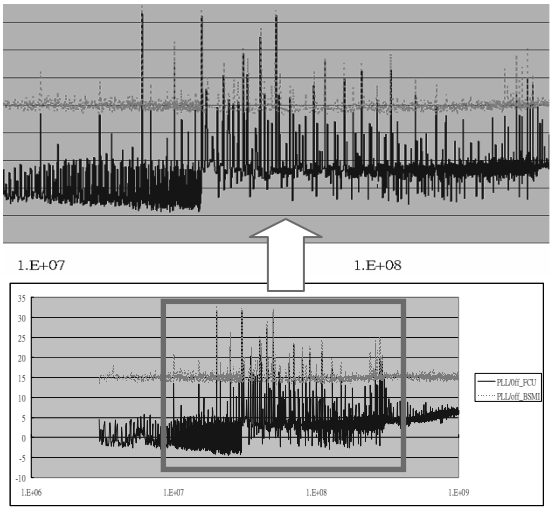

Fig. 6 PLL/off compare FCC with FCU on frequency domain

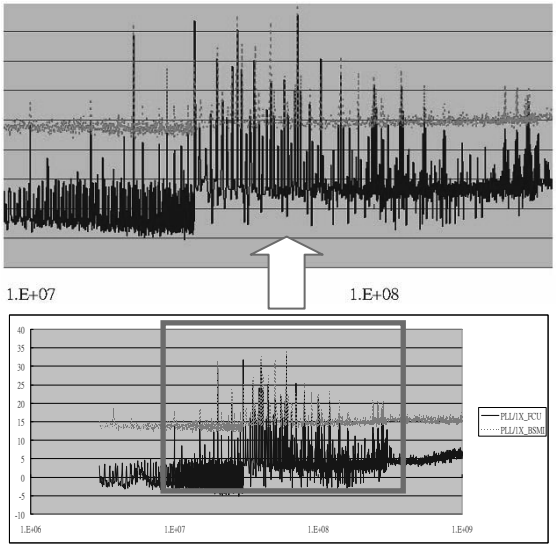

Fig. 7 PLL/1X (10 MHz) compare FCC with FCU on frequency domain

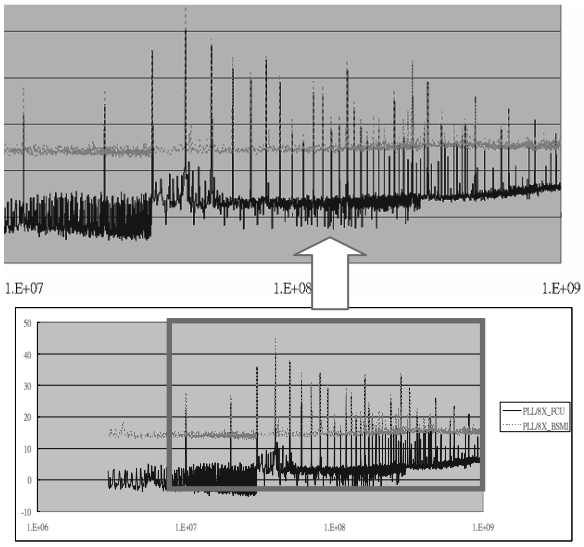

Fig. 8 PLL/8X (80 MHz) compare FCC with FCU on frequency domain

B. Different PLL settings comparison

The PLL is set to PLL/off (PLL turns off), PLL/1X (PLL turns on and sets to 1X) and PLL/8X (PLL turns on and sets to 8X) by three programs to observe the EMI behaviors.

PLL/off and PLL/1X comparison: Fig. 9 shows the EMI difference between PLL/off and PLL/1X. Generally, PLL/1X EMI is larger than that of PLL/off. The Maximum difference is 23.3 dBμV at 60 MHz. At some EMI frequency PLL/off has higher value than that of PLL/1X. The Maximum differencee is 15.35 dBμV at 290 MHz.

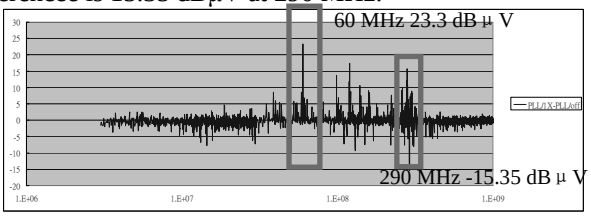

Fig. 9 PLL/1X EMI value decrease PLL/off EMI value

PLL/1X and PLL/8X comparison: Fig. 10 shows the EMI difference between PLL/1X and PLL/8X. Generally, PLL/8X EMI is larger than that of PLL/1X. The Maximum difference is 22.66 dBμV at 280 MHz. At some EMI frequency PLL/1X has higher value than that of PLL/8X. The Maximum difference is 22.88 dBμV at 25 MHz.

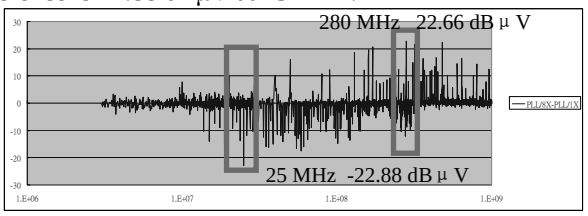

Fig. 10 PLL/8X EMI value decrease PLL/1X EMI value

PLL/off and PLL/8X comparison: Fig. 11 shows the EMI difference between PLL/off and PLL/8X. Generally, PLL/8X EMI is larger than that of PLL/off. The Maximum difference is 23.67 dBμV at 320 MHz. At some EMI frequency PLL/off has higher value than that of PLL/8X. The Maximum difference is 25.44 dBμV at 25 MHz.

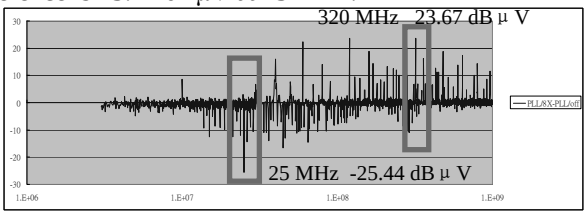

Fig. 11 PLL/8X EMI value decrease PLL/off EMI value

From the measurement results, different program setups of the programmable PLL indeed show the impact to the EMI behavior. Generally, the EMI is higher as the internal frequency get higher across the bandwidth. However, the observations also show that at some specific frequency (PLL/off at 290 MHz and PLL/8X at 25 MHz), the situations are reversed. That is, when PLL is turned off (or slower), the emission is higher than PLL turn on (or faster). This is an interesting research topic to be further investigated.

The different PLL settings of the same program function indeed have impacts on EMI behavior. From the measurement result, at some frequency the EMI differences can be up to 20 ~ 35 dBμV.

V. CONCLUSION

We use PIC micro-controller as an example to demonstrate the software program has the impact on the IC EMI behavior of an embedded system. The system includes a programmable PLL embedded in a micro-controller. The design and measurement of the IC EMI are according to IEC standard.

Generally, the measurements and observations are reasonable across the bandwidth — the higher PLL frequency the higher EMI. However, to our surprise, at some frequencies (25 MHz and 290 MHz), the phenomena are reversed.

Therefore, it is possible to control PLL by program to change the behavior of EMI and reduce EMI at specific frequencies through software which may save the hardware cost.

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