Comparative study for the application of DSP processor and Microcontroller for PV systems

Subramanya Bhat, Nagaraja H N

Abstract—In the proposed study the application of Digital Signal Processor (DSP), microcontroller and conventional hardware circuit using SG3524 to generate PWM waves for triggering the MOSFET switch in buck-boost converter for Photo voltaic (PV) system is discussed. They are compared in terms of speed, accuracy and cost. The implementation of PWM algorithm in DSP TMS 2808 and hardware circuit to generate PWM is discussed in detail. The proposed study forms the basis for the selection which helps in generating PWM waves and also gives better insight into programming of DSP TMS 2808 using different header files, source files and command files.

Index Terms—buck-boost converter, computational power, hardware circuitry, motion control

I. INTRODUCTION

In recent years renewable energy has gained more importance, due to fossil fuel exhaustion and increase in environmental problems because of conventional power generation. In the proposed study, Photo voltaic generation is addressed as this is a promising renewable energy source for Industry, commercial and rural applications. The PV generation is used in many applications such as water pumping, home power supply, hospital power supply satellite power supply, etc. The initial cost of PV system is high but its maintenance cost is low and it is pollution free. Now days, DSP’s are used for controlling the DC motor, stepper motor and induction motor. The DSP based electromechanical motion control is gaining more importance. Hamid A Toliyat [2] discussed the interfacing of DSP with DC motor, stepper motor and induction motor. In an inverting buck-boost converter one MOSFET switch is used, but in non inverting type two MOSFET switches are used which requires two PWM waves which are out of phase by 180 degrees [3]. The DSP TMS 2808 can provide the same, but a microcontroller can provide only one PWM wave [4]. The disadvantage of PIC microcontroller is that the length of the program is big because of using RISC (35 instructions). Program memory is not accessible and only one single accumulator is present. The advantages of PIC Microcontroller are that they are reliable percentage of malfunction of PIC is less and performance of the PIC is very fast because of RISC architecture but less to DSP. Power consumption is also very less when compared to hardware circuit or DSP. The interfacing of PIC microcontroller with buck-boost converter is very easy, and so we can connect analog devices directly without any extra circuitry and use them. Programming is also very easy when compared to DSP.

II. COMPARISON

The DSP based buck-boost converter gives a fast response improving the system stability. Hardware circuitry or microcontroller is less accurate and most of the solar energy cannot be converted into electrical energy. In industry and commercial applications DSP is used for automation purposes and the same DSP can be used to implement control algorithms so as to get maximum electrical energy from solar energy. The DSP is more accurate and it will work in real time. The efficient utilization of resources such as DSP is achieved as we can use the same DSP for generating PWM wave. The DSP can be programmed using flash programmer and can be used in fields for PV system. The DSP processors are becoming cheaper with more computational power when compared to microcontrollers.

The hardware circuitry using SG3524 used for generating PWM waves will not permit easy system modifications, but the microcontroller and DSP based permit the same. The DSP used in industry and commercial applications can be used in PV generation system since the DSP is computationally more powerful when compared to microcontroller. The microcontroller clock speed is low and is used for PV systems supplying residential applications.[4].The output of microcontroller needs a gate driver circuit to trigger the switch in the converter.
III. PWM IMPLEMENTATION USING HARDWARE CIRCUIT

The PWM generation using hardware circuitry is shown in Fig. 1. The SG3524 Integrated Circuit (IC) is used to switch ON the MOSFET. This IC has an op-amp, comparator, saw-tooth generator, reference voltage and two output drivers. To generate a square wave using SG3524, the externally connected RT and CT values are adjusted so that the desired switching frequency is found. The discharge time of CT determines the pulse width of the oscillator output pulse. The frequency of the saw-tooth wave (it is the same as the switching frequency of the circuit) at CT (pin 7) is measured. To vary the duty cycle of the waveform, the 10k potentiometer is adjusted.

![Fig.1 PWM generation using SG3524](image)

The advantages of hardware circuit are that they are cheap and simple. The disadvantages are that they will not permit easy modifications. In order to change the amplitude and duty cycle, the circuit components should be changed. But in DSP or microcontroller the amplitude and duty cycle can easily be changed by making changes in programming.

IV. PWM IMPLEMENTATION USING DSP

In the proposed study DSP TMS 2808 processor is programmed to generate 8 different PWM waves. The code composer studio is used to write programs for DSP. For generating PWM wave header files, source files and command files are required. The different header files used are DSP280x_Adc.h, DSP280x_CpuTimers.h, DSP280x_DefaultIsr.h, DSP280x_Device.h, DSP280x_ECan.h, DSP280x_EPwm.h, DSP280X_EPwm_defines.h, DSP280x_EQep.h, DSP280x_I2c.h, DSP280x_I2cExample.h, DSP280x_PieCtrl.h, DSP280x_PieVect.h, DSP280x_Sci.h, DSP280x_Spi.h, DSP280x_SysCtrl.h and DSP280x_XIntrupt.h.

DSP280x_Adc.h this is used for DSP280x Device ADC Register Definitions. The DSP280x_CpuTimers.h is used for DSP280x Devices Default Interrupt Service Routines Definitions. DSP280x_DefaultIsr.h is used for DSP280x Devices Default Interrupt Service Routines Definitions. DSP280x_Device.h is used for DSP280x Device Definitions. DSP280x_ECan.h is used for DSP280x Device ECan Register Definitions. DSP280x_EPwm.h is used for DSP280x Enhanced PWM Module Register Bit Definitions. DSP280x_EPwmDefines.h is used for DSP280x Enhanced PWM Module Bit Definitions. DSP280x_EQep.h is used to DSP280x Enhanced Quadrature Encoder Pulse Module Register Bit Definitions. DSP280x_I2c.h is used for DSP280x I2C Example Code Definitions. DSP280x_PieCtrl.h is used for DSP280x Device PIE Control Register Definitions. DSP280x_PieVect.h is used for DSP280x Devices PIE Vector Table Definitions. DSP280x_Sci.h is used for DSP280x Device SCI Register Definitions. DSP280x_Spi.h is used for DSP280x Device SPI Register Definitions.
The source files used are DSP280x_CodeStartBranch.asm, DSP280x_CpuTimers.c, DSP280x_DefaultIsr.c, DSP280x_EPwm.c, DSP280x_GlobalVariableDefs.c, DSP280x_PieCtrl.c, DSP280x_PieVect.c, DSP280x_SysCtrl.c, and Example_280xEPwmUpDownAQ.c. DSP280x_CodeStartBranch.asm is used for redirecting code execution after boot. DSP280x_CpuTimers.c is used for 32-bit Timers Initialization & Support Functions. DSP280x_DefaultIsr.c is used for DSP280x Device Default Interrupt Service Routines. This file contains shell ISR routines for the 280x PIE vector table. These shell ISR routines can be used to populate the entire PIE vector table during device debug. In this manner if an interrupt is taken during firmware development, there will always be an ISR to catch it. As development progresses, these ISR routines can be eliminated and replaced with the user's own ISR routines for each interrupt. Since these shell ISRs include infinite loops they will typically not be included as-is in the final production firmware. DSP280x_EPwm.c is used for DSP280x ePWM Initialization & Support Functions. DSP280x_GlobalVariableDefs.c is used for DSP280x Global Variables and Data Section Programs. DSP280x_PieCtrl.c is used for DSP280x Device PIE Control Register Initialization Functions. DSP280x_PieVect.c is used for DSP280x Devices PIE Vector Table Initialization Functions. DSP280x_SysCtrl.c is used for DSP280x Device System Control Initialization & Support Functions. Example_280xEPwmUpDownAQ.c is used for Action Qualifier Module using up or down count. This program uses the following assumptions: This program requires the DSP280x header files. The ePWM1-ePWM3 pins are monitored on an oscilloscope as follows. The ePWM1A is on GPIO0, ePWM1B is on GPIO1, ePWM2A is on GPIO2, ePWM2B is on GPIO3, ePWM3A is on GPIO4, ePWM3B is on GPIO5. The DSP 2808 Boot Mode table is shown in TABLE I.

<table>
<thead>
<tr>
<th>Boot mode</th>
<th>GPIO18 SPICLK</th>
<th>SPICTXB</th>
<th>GPIO29 SCITXD</th>
<th>GPIO34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SCI-A</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SPI-A</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>I2C-A</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ECAN-A</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SARAM</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>OTP</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>I/O</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

This example configures ePWM1, ePWM2, ePWM3 to produce a waveform with independent modulation on EPWMxA and EPWMxB. The compare values CMPA and CMPB are modified within the ePWM's ISR. The TB counter is in up or down count mode for this example. The ePWM1A/B, ePWM2A/B and ePWM3A/B waveforms are viewed on an oscilloscope. The Command Files used are 2808_eZdsp_RAM_Ink.cmd and DSP280x_Headers_nonBIOS.cmd. The 2808_eZdsp_RAM_Ink.cmd is used for 2808 examples that run out of RAM. This ONLY includes SARAM that is not secure on the 2808 device.

The DSP280x_Headers_nonBIOS.cmd is for use in Non-BIOS applications. This is Linker command file to place the peripheral structures used within the DSP280x header files into the correct memory mapped locations. This version of the file includes the Pie Vector Table structure. For BIOS applications, we will use the DSP280x_Headers_BIOS.cmd file which does not include the Pie Vector Table structure.

V. RESULTS AND DISCUSSION

The PWM waveforms generated from SG3524 is shown in Fig. 2. The waveforms generated at different PWM pins are shown in Fig.3, Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, Fig.9 and Fig.10. It is clear from the waveforms that we can get pulses of different widths depending upon analog input to DSP. The amplitude is more than 3V which is more than the threshold voltage of MOSFET. There are 8 different PWM waveforms which can be used to trigger 8 MOSFET switches. Since the PWM amplitude is more than the threshold voltage of MOSFET, no gate driver circuit is required. The DSP interfaced for generating PWM waves is shown in Fig.11. The comparison between
PWM generation from microcontroller, DSP and hardware circuit is given in TABLE II. The comparison is done in terms of speed, accuracy, cost and computational power.

![PWM waves from SG3524](image)

![PWM from DSP kit Pin No.1](image)

![PWM from DSP kit Pin No.2](image)

![PWM from DSP kit Pin No.3](image)

![PWM from DSP kit Pin No.4](image)
Fig. 11 DSP TMS 2808 for PV system
VI. CONCLUSION

In the proposed study a comparison between hardware circuitry, microcontroller and DSP for PV application is discussed. DSP is now playing an important role in electro-mechanical motion control. The proposed study helps in integrating DSP into motion control. This proposed study will become the ground work for interfacing DSP into PV system. Apart from converters even inverters in PV system can be interfaced to DSP. But we need many microcontrollers to control converter and inverter in PV system. But single DSP can control both converter and inverter. Now DSP PIC’s are available in market which combines the advantages of microcontroller and DSP. The files used for generating PWM from DSP can be used to implement PWM generation in DSPPIC.

REFERENCES


AUTHOR BIOGRAPHY

Prof. Subramanya Bhat is currently pursuing Ph.D, under Visvesvaraya Technological University, Belgaum, India. He is currently working as an Associate professor in the department of Electronics & Communication Engineering, Canara Engineering College, and Mangalore, India. He has presented more than 15 papers in National and International conferences and Journals. His research interests include power electronics, signal processing, control systems and image processing. He has given more than 10 invited talks in his research field. He was awarded with many best paper awards in National and International conferences.
Dr. H.N. Nagaraja, presently working as Director of Indus Institute of Technology and Engineering, did his graduation in Electrical and Electronics Engineering from Government college of Engineering, Davanagere. Post-graduation from Walchand college of Engineering, Sangli, and Doctorate from Nation’s one of the premier institute Indian Institute of Technology, Kharagpur-West Bengal. Dr. Nagaraja has a vast experience of 27 years in teaching and 9 years in Research. He has presented 40 papers in the national and international reputed journals and conferences. He has also given 22 invited talks at various Engineering colleges. He has presented research papers at Japan Malasia and Hongkong. His fields of interests are Power supply design, Power Electronics, Renewable Energy Sources, Microprocessors, Network Analysis, etc.