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Response of MSP-EXP430G2 LaunchPad Development Board to Electrostatic Discharge

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Abstract: In today's highly competitive markets, efficient ESD protection has became an integral part of IC/ASIC design for system reliability. Reliable circuit protection following IEC61000-4-2 industry's standard is usually accomplished by the implementation of ESD protection devices at critical pins. The IEC 61000-4-2 standard addresses ESD transients in electronic systems. It defines immunity requirements for ESD which can be coupled into the equipment, systems or system boards directly or through radiation (air discharge). The Human Body Model is considered as a valid representation of worst case ESD stress. Discharge into equipment may be through direct contact (contact discharge method) or just prior to contact (air discharge method). Direct and Indirect ESD test has been conducted on the MSP-EXP430G2 Launch Pad Development Board which has the state-of-the-art protection for system level ESD. The primary purpose of this test is to determine the immunity of MSP 430 system to external ESD events during operation. We have observed all the IEC specified system-level failure criteria classifications during the system level ESD test.

Keywords: System level ESD, Lauch pad MSP 430, IEC 61000-4-2, Contact discharge and Air discharge

I. INTRODUCTION

The MSP-EXP430G2 low-cost experimental board called LaunchPad is a complete development solution of the new Texas Instruments MSP430G2xx series [1], [2]. Its integrated USB-based emulator offers all the hardware and software necessary to develop applications for all MSP430G2xx series devices. The LaunchPad has an integrated DIP target socket that supports up to 20 pins as shown in Fig. 1, allowing MSP430 Value Line devices to be dropped into the LaunchPad board. The MSP-EXP430G2 uses the IAR Embedded Workbench Integrated Development Environment (IDE) or Code Composer Studio (CCS) to write, download, and debug an application.

A. Jumper connection between emulator and target device

1. TEST - Test mode for JTAG pins / Spy-Bi-Wire test clock input during programming and test
2. RST - Reset / Spy-Bi-Wire test data input/output during programming and test
3. RXD - UART receive data input
4. TXD - UART transmit data output
5. V_{CC} - Target socket power supply voltage (power consumption test jumper)

B. Programming example

The code used for testing the working of LaunchPad MSP-EXP430G2 shown in Fig. 2 is the one producing a pulse width modulation (PWM) wave. The output is filtered out using a band pass filter (BPF) as shown in Fig 3. The PWM wave is converted to a sine wave. The output of the LaunchPad and the band pass filter is shown in the Fig. 4.

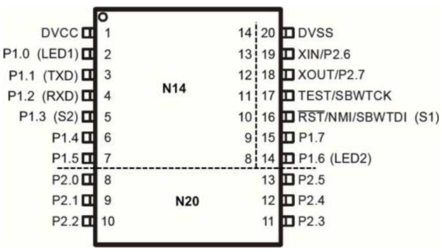

Fig 1 Device pinouts

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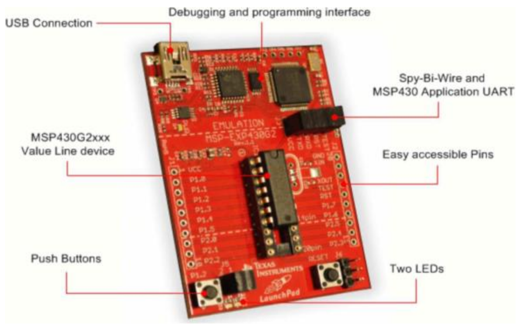

Fig 2. MSP-EXP430G2 LaunchPad overview

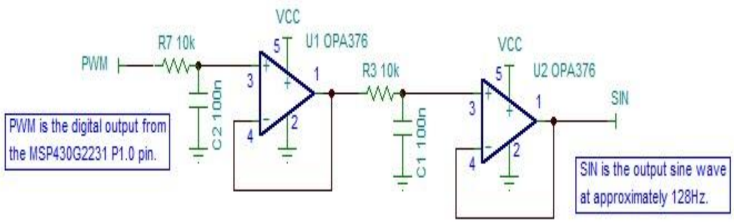

Fig 3. BPF circuit

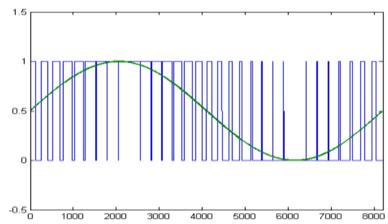

Fig 4 The output of LaunchPad and band pass filter

II. Effects of ESD

When testing a system to system-level standard [3-8] the end-products are required to remain functional in the presence of or following an ESD event. The IEC specified system-level failure criteria classifications are as follows:

- Normal performance within limits specified by the manufacturer.
- Temporary loss of function or degradation of performance that ceases after the disturbance ceases. Equipment under test recovers its normal performance without operator intervention.
- Temporary loss of function or degradation of performance. Recovery requires operator intervention.
- Temporary loss of function or degradation of performance which is not recoverable, caused by damage to hardware or software, or loss of data.

A. *Indirect Discharge at Horizontal Coupling Plane (HCP) and Vertical Coupling Plane (VCP):*

For an indirect discharge of 4kV at a distance of 0.3m on the HCP, the PWM waveform from the LaunchPad is unaffected but there is a transient of 8V in the sine wave output of the discrete circuit i.e, the band pass Filter as shown in Fig. 5. When a pulse is discharged at a voltage of 8kV at a distance of 0.3m on the HCP, the PWM waveform from the LaunchPad is unaffected but there is a transient of 8V in the sine wave output of the discrete BPF circuit as shown in Fig. 6. For an indirect discharge of 15kV at a distance of 0.3m on the HCP, the PWM waveform from the LaunchPad is unaffected but there is again a transient of 8V in the sine wave output of the discrete BPF circuit as shown in Fig. 7. When a pulse is discharged at a voltage of 4kV in the top left corner of the VCP, the PWM waveform from the LaunchPad is unaffected but there is a large double transient in the sine wave output of the discrete circuit as shown in Fig. 8.

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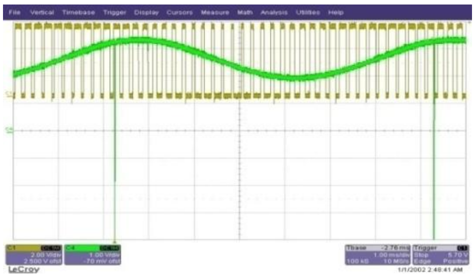

Fig 5 Discharge Voltage of 4kV at a distance of 0.3m.

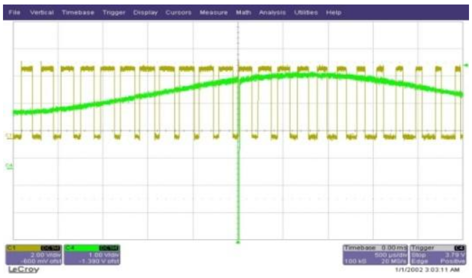

Fig 6 Discharge Voltage of 8kV at a distance of 0.3m

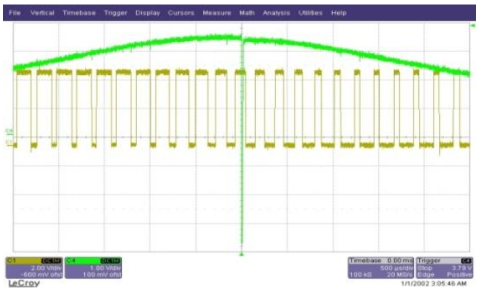

Fig 7 Discharge Voltage of 15kV at a distance of 0.3m

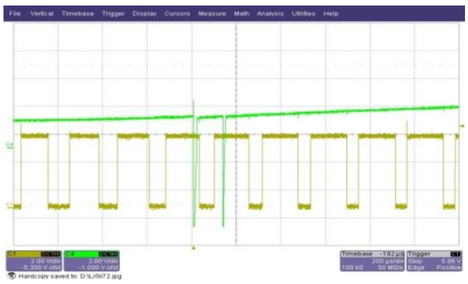

Fig 8 Discharge of 4kV on the VCP

When a pulse is discharged at a voltage of 15kV in the top right corner of the VCP, the PWM waveform from the LaunchPad is unaffected and the sine wave output of the discrete BPF circuit has transients as shown in Fig. 9

B. *Direct Air Discharge to the GPIO pins*

For a Discharge of 2kV, the PWM waveform from the LaunchPad has a dip in the voltage losing its modulated pulse width characteristic for around 0.2ms whereas there is a large transient in the sine wave and also a change in the sine waveform as shown in Fig. 10.

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For a discharge of 4kV, the PWM waveform from the LaunchPad goes to zero at the point of occurrence of the trigger whereas the sine wave output of the discrete BPF circuit gradually decreases to zero as shown in Fig. 11. For a discharge of 8kV, the PWM waveform from the LaunchPad goes to zero at the point of occurrence of the trigger whereas the sine wave output of the discrete BPF circuit decreases to an intermediate value as shown in Fig. 12. All these waveforms come back to their original shape on hard RESET (power ON).

Fig 9 Discharge of 15kV on the VCP

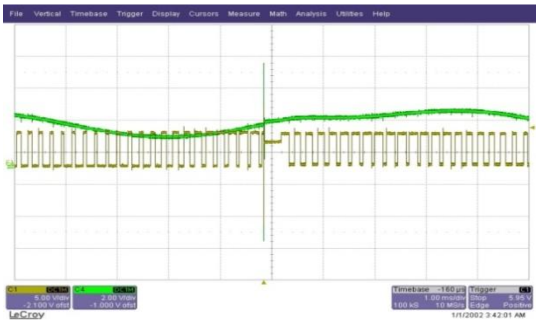

Fig 10 Discharge Voltage of 2kV at GPIO pins

Fig 11 Discharge voltage of 4kV at GPIO pins

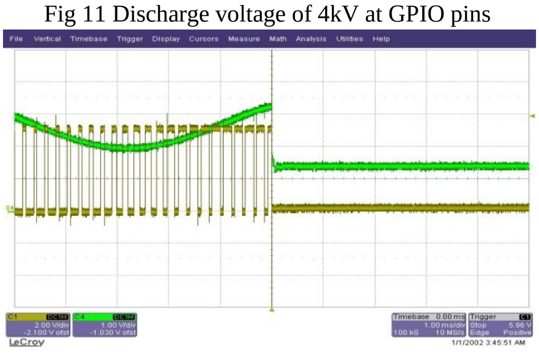

Fig 12 Discharge voltage of 8kV at GPIO pins

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C. *Direct Contact Discharge:*

The initial output of the PWM waveform and the sine waveform is shown in Fig. 13. When a discharge of 8kV is given to the output pin, the value of the output of the sine wave from the discrete BPF becomes zero and the voltage of the PWM waveform is reduced from 5V to 2V as shown in Fig. 14. A hard RESET restores the PWM output and sine wave of BPF. When a discharge of 8kV is given to the reset pin, there is a change in the PWM output and it loses its modulated pulse width character for some time as shown in Fig. 15. When a discharge voltage of 8kV is given to the pins of the Jumper Array i.e to Gnd pin, the output reduced to 0.4V but resets on power ON; to V_{cc} pin, the output becomes zero and resets on power ON and to Rx-Tx pins, the output becomes zero and did not RESET on power ON as shown in Fig. 16. Post ESD test analysis shows that the Microcontroller IC MSP 430G2231 has been damaged.

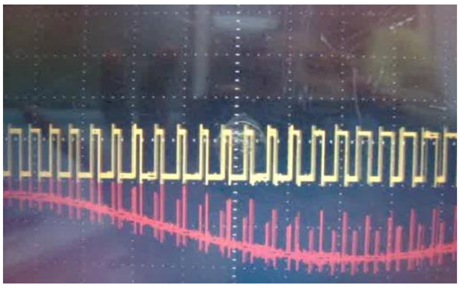

Fig 13 Initial PWM waveform and the sine waveform

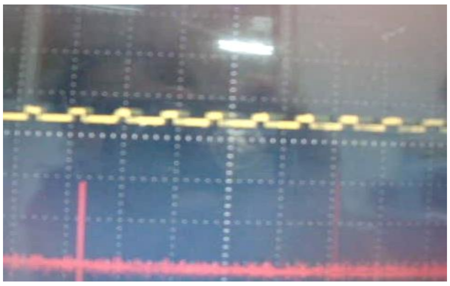

Fig 14. Reduced output

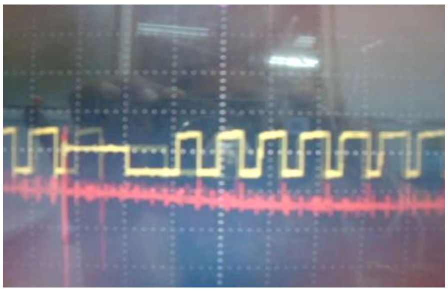

Fig 15. PWM output with a change in the waveform

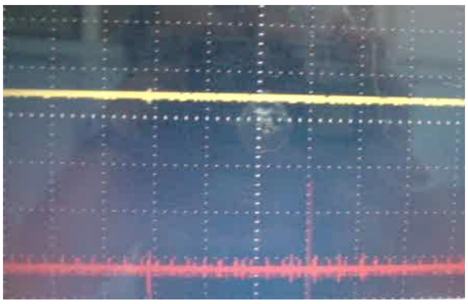

Fig 16. Output at zero

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III. CONCLUSION

The original equipment manufacturer (OEM) has taken into account the system level considerations for ESD and hence the output is restored on a hard RESET [9],[10]. The TI MSP-EXP430G2 LaunchPad development board has been designed taking into account the various system-level ESD considerations like dedicated ground plane because solid ground plane provides continuous, low-impedance path for return current and ESD testing throughout design and development which helps identify and fix weak ESD spots in the system. The following IEC specified system-level failure criteria classifications are observed.

1. Normal performance within specification limits

• MSP430 is affected to a certain extent by the system-level ESD stress but continues to execute without any intervention. The launchPad works normally within specification limits.

2. Temporary degradation or loss of function or performance which is self-recoverable or requires operator intervention (hard RESET)

• For indirect air discharge of 2, 4, 8, 15 kV; direct air discharge and contact discharge of 2kV the launch pad and BPF circuit are affected but recovered without reset.

3. Temporary loss of function or degradation of performance which is not recoverable, caused by damage to hardware or software, or loss of data or Permanent degradation

• For direct air discharge of 4kV and 8kV, the PWM waveform from the LaunchPad goes to zero at the point of occurrence of the trigger whereas the sine wave output of the discrete BPF circuit decreases to an intermediate value. On hard reset the output of the launchpad is restored but the opamp ICs in the bandpass filter are spoilt.

• Only when contact discharge of 8kV was given to the pins of the jumper array it was found on post ESD test analysis that the MSP 430G2231 IC is damaged. The communication port of the microcontroller MSP 430G2231 is damaged as it was not communicating with the software and the program is not executable. Once the microcontroller IC has been changed the MSP 430 launchPad is functioning fine.

The launchPad is quite immune to ESD owing to its careful design and ESD considerations, therefore the device soft or hard resets in majority of the ESD stress it is subjected to.

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BIOGRAPHY

Prof.. Rajashree Narendra completed her Bachelors degree in Electronics and Communication Engineering from University of Mysore, India in 1988 and Masters degree in the area of Optical Fiber Communication at University of Alberta, Edmonton, Canada in 1992. She is currently persuing her Doctoral program in the area of EMI/EMC in Electronics and Communication Engineering at UVCE, Bangalore University, India.

Major field of study is Integrated Optical Devices, Electrostatic discharge and EMI/EMC. She has about 24 years of research and teaching experience. She worked as a Research Engineer at TR Laboratories, Edmonton, Canada. She worked as Scientist at CEERI, CSIR Labs, Pilani, India. She is currently Professor and Head, Department of Telecommunication, BNM Institute of Technology, Bangalore. She has published and presented papers in IEEE Transactions, Photonics

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Technology Letters, SPIE, IEEE–LEOS International Conference, Saratov Fall Meet at Russia, Asia Pacific Symposium on EMC, China, PIERS–KL,Malaysia, IEEE AEMC-Kolkata and INCEMIC-Bangalore.

Dr. M.L. Sudheer received his BE degree in Electrical Engineering from UVCE, Bangalore University in 1980and M.Tech in Industrial Electronics from NIT-K, Suratkal and Ph.D from CEDT, Indian Institute of Science, Bangalore in 2000. He is presently working as Professor in the Department of Electronics & Communication, UVCE, Bangalore University, India.
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Dr D.C. Pande did his PhD in 1982 from University of Allahabad. Since November 1981, he is with LRDE, where he is involved in Design & Development of Electromagnetic Interference Control Techniques for Ground Based, Airborne and Shipborne equipments and systems. He is one of the pioneer scientists who had started research activities in the field of NEMP and High Power Microwave (HPM) in India.
Presently he is involved in design, development and evaluation of various types of antennas for different Radar programs. He is a founder Life Member of SEMCE (I); at present he is the Chairman of the Society. He was a member for the Department of Electronics Committee for evolving National Standards regarding Electromagnetic Emissions. He was awarded Certificate of Achievements by SUMMA Foundation, USA, Commendable Certificate by IGMDP Program in 1990, Megha Nath Saha Memorial Award of IETE in 1994, EMC Engineer of the Year 1998 of SEMCE (I) and Lab Scientist of the Year 2003 by DRDO, National Science Day Award 2004 and DRDO Scientist of the Year Award 2005. Presently he is Scientist H, Outstanding Scientist and Director (Technologies) in Electronics and Radar Development Establishment (LRDE), Bangalore, India.