Application Report

SPMA071–March 2014

Thermal Printer Reference Design Using TM4C1233H6PM

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ABSTRACT

Thermal printers are very common due to their wide-spread use in so many devices in our day-to-day life. Some of them are handheld devices used for point-of-sales, ticketing machines, metering, and so forth. The benefits of thermal printers are compelling. There is no toner, ink or ribbons required for a thermal printer. A thermal receipt printer uses a printhead with few moving parts and it fits in a thin space about three inches across. By contrast, the standard receipt printer is composed of about 20 moving parts and electrical devices, and takes up at least twice the space. Nowadays, thermal printer mechanisms are even available with an integrated electro-mechanical paper cutter in it. All of these features make thermal printers a right choice in a wide variety of applications.

This application report discusses the complete hardware and software required for a thermal printer solution based on Texas Instruments Tiva™ controllers. Tiva controllers are 32-bit ARM® Cortex®-M4 80-MHz processor core with IEEE754-compliant single-precision Floating-Point Unit (FPU), on-chip memory, featuring 256 KB single-cycle Flash, 32 KB single-cycle SRAM; internal ROM loaded with TivaWare™ for C Series software; 2KB EEPROM and several other features.

With all the above hardware features and the graphics library support available for Tiva controllers makes it easy to do the text rendering and simultaneous printing required for thermal printing.

Project collateral and source code discussed in this application report can be downloaded from the following URL: http://www.ti.com/lit/zip/spma071.

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  - Universal Serial Bus (USB)
- Software features
  - Support 2 inch thermal heads
  - Can be extended easily for 3 inch printer head
  - Wide support for fonts
    - Multi-sized fonts
    - Italics fonts
    - Bold fonts
  - Also support Image
  - Architecture supports implementation of escape commands

This application report explains the working of the software and hardware required for building a thermal printer solution.

The hardware for the system is designed around Texas Instruments TM4C1233H6PM Microcontroller. It is a 80 Mhz processor with 256Kbytes of Flash and 32Kbytes of internal RAM. There are two motor driver sections implemented in the system: one motor driver section for the printer motor and the other for the paper cutter integrated to the printing mechanism. The motor driver sections are implemented using the DRV8834 motor driver ICs from Texas Instruments. The hardware also provides the facility for communication using UART and USB interfaces through the inbuilt peripherals available inside the controller.

The thermal printer firmware is running in a foreground and background execution approach. It utilizes various peripheral interrupts available in the microcontroller to achieve the performance. For example, the design utilizes the UART interrupts for collecting the data from an external host, uses the timer interrupt for accurately controlling the heating strobes of the printer mechanisms, and so forth. The font tables (used for text rendering, and so forth) are stored in the built in Flash. The font tables are stored in a compressed format for saving the application Flash. The images are stored in the form of C arrays.

The various functions performed by the firmware are listed below:

- Rendering of the text character received through the communication port to the printable image
- Logo printing using the onboard switch provided
- Font management by selecting the appropriate Font Table
- Increasing or decreasing the height of the printed text
- Increasing or decreasing the width of the printed text
- Precisely controlling the printing strobes as per the timing specification of the mechanism
- Auto cutter facility using the built-in paper cutter
- Provides a basic set of escape commands for data and commands
- Provision for adding more escape commands for data and commands
- Monitor the battery voltage of the system

2 System Block Diagram

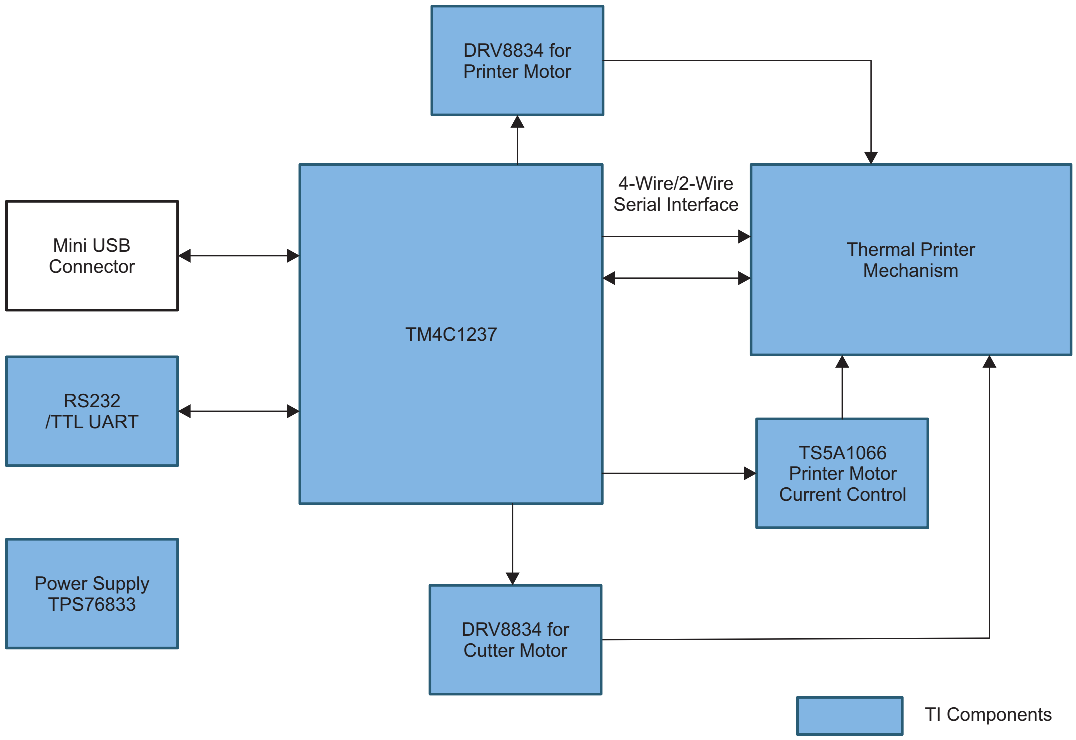

Figure 1. System Block Diagram

3 Circuit Diagram

For the schematic details, see Appendix A.

4 Firmware

4.1 Flowchart

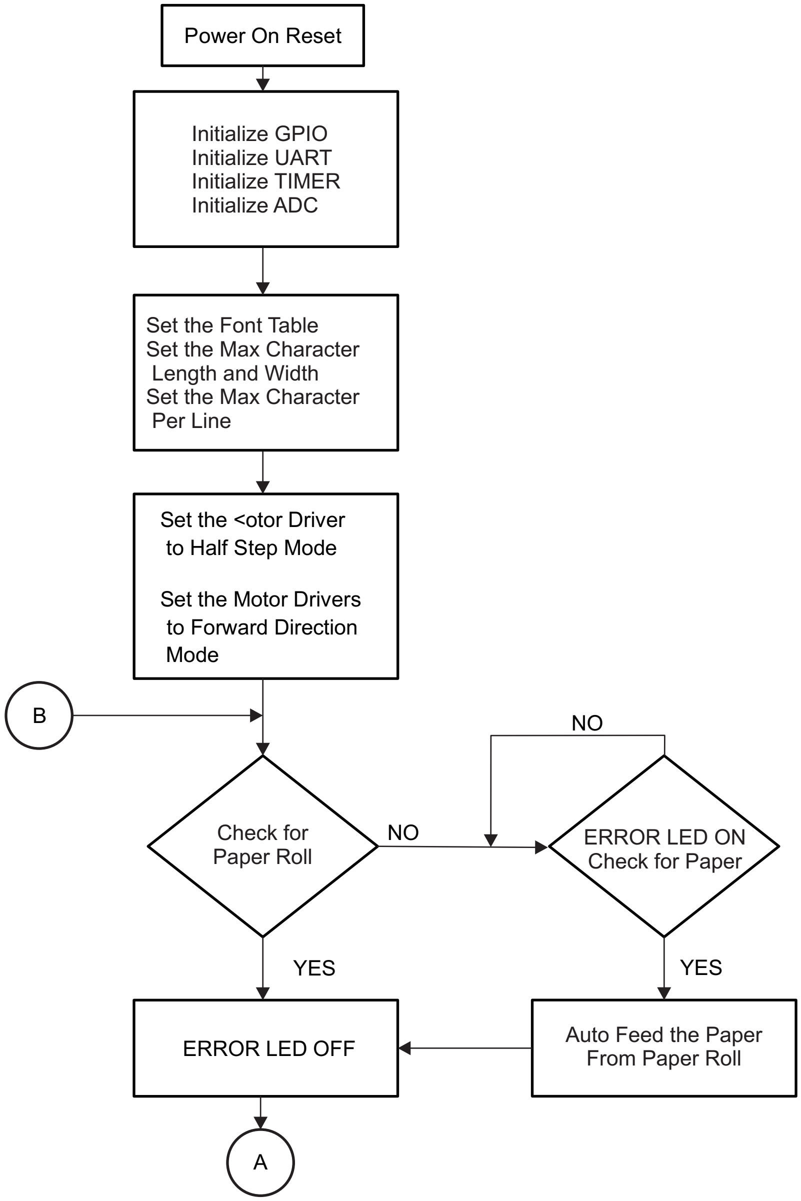

Figure 2. Flowchart - Part 1

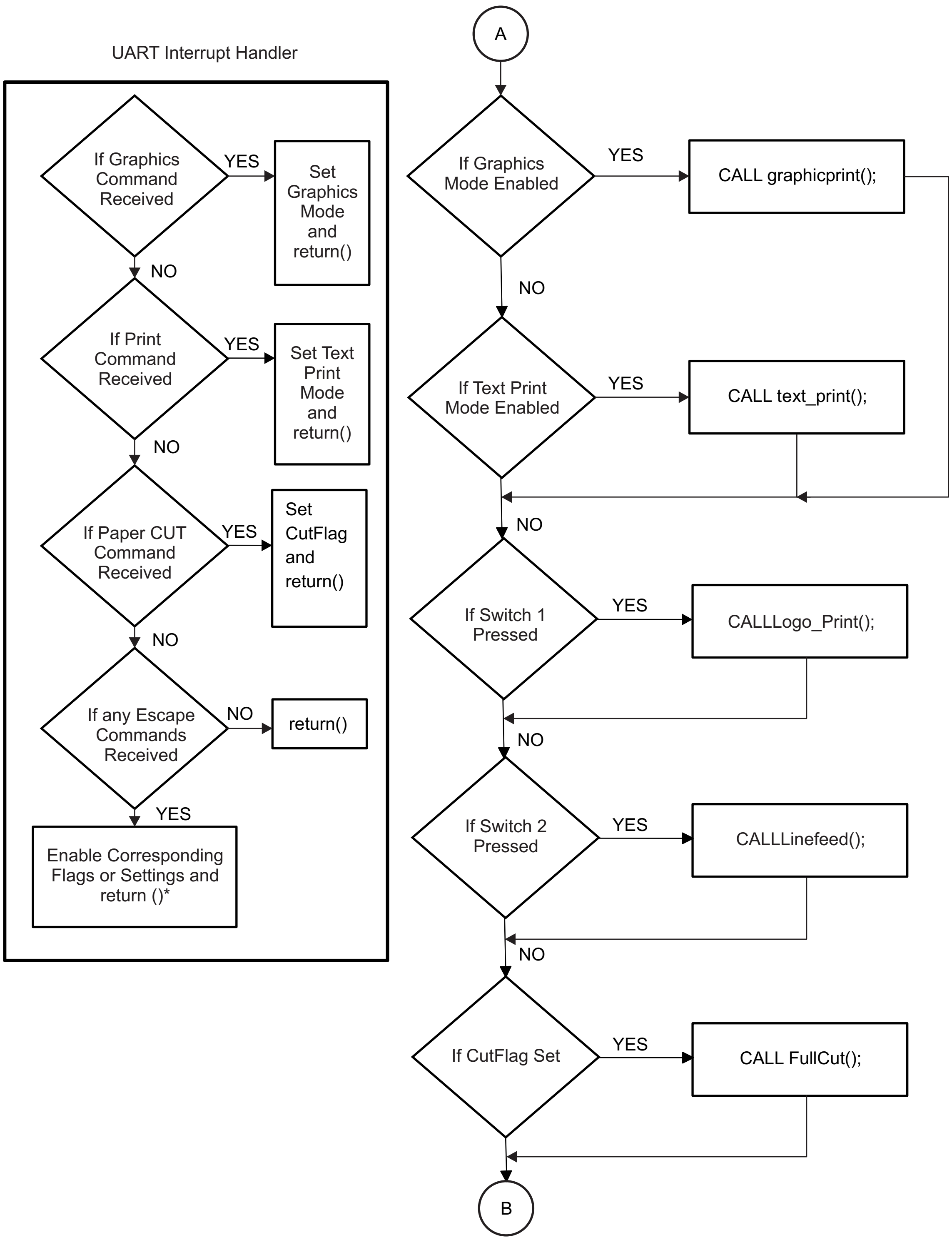

Figure 3. Flowchart - Part 2

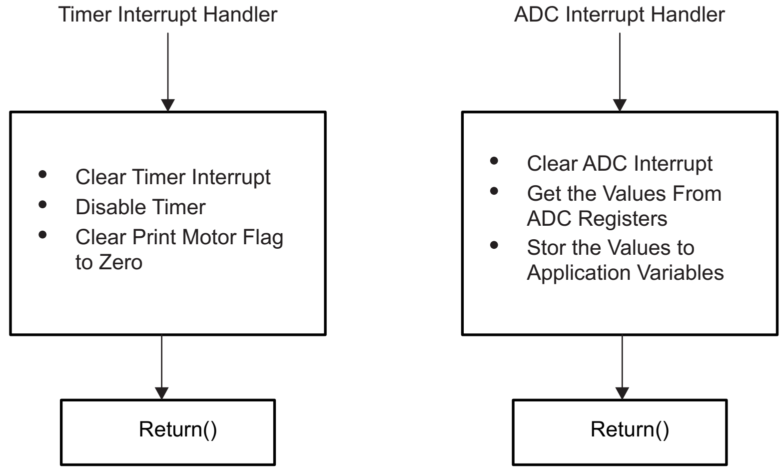

Figure 4. Software Flowchart

5 Theory of Operation

5.1 General Information About Thermal Printers

Thermal printing is a non-impact method of creating images on paper and synthetic film. The process applies heat from a thermal printhead onto thermal material. The base material used in the thermal printing process may be selected from a variety of paper grades or synthetic films (PP, PE, or PET) with a special chemical coating applied to one side to make it sensitive to heat.

Thermal printing has a number of important advantages over traditional printing processes; it is fast, clean, quiet, reliable and easy to maintain. There are a limited number of mechanical parts, no messy ribbons or toners, and no inking devices are needed to create the image.

Since thermal printers only have one or two moving components, they are very reliable and economical to operate and maintenance costs are extremely low. The entire system is compact, simple to operate and suitable for use in virtually all applications. Thermal printheads are usually much smaller and lighter than the printing elements used by other imaging processes, so thermal printers are suitable when compact size, portability and on-demand printing are needed. At the same time, a sharp and precise image of excellent quality is produced consistently and quickly by properly matching the thermal paper to the printhead by varying the chemical coating formulation.

In recent years, microprocessors have been installed to control printhead operation with major improvements in image sharpness and clarity. A thermal printhead has a large number of tiny resistors, which individually react to convert an electrical impulse into heat. The heat from the printhead on thermal material creates a reaction with the chemical coating to produce an image. The image is produced within milliseconds of contact and is normally black in color. The depth and range of colors may be produced by varying the chemical formulation applied to the base material.

The quality and performance of thermal printing depends heavily on the careful matching of thermal material to printhead equipment specification. As a result, a range of thermal materials is used across a wide spectrum of thermal printers for different applications. To give the required physical characteristics and properties, the type of base material - paper, board, or synthetic film - varies from application to application, as does the thickness and weight of various base materials.

5.2 Specification of the Thermal Printer Head Used With This Document

The thermal printer mechanism used for this application report is from Seiko. The model number is CAPD245D-E. It has a built-in auto-cutter mechanism integrated into it. Table 1 shows the electrical specification for CAPD245D-E.

Table 1. Electrical Specification for CAPD245D-E

Items	Specifications			
	CAPD245		CAPD345	
	CAPD245D	CAPD245E	CAPD345D	CAPD345E
Printing method	Thermal dot lin printing			
Total dots per line	384 dots		576 dots	
Printable dots per line	384 dots		576 dots	
Simultaneously activated dots	96 dots		96 dots	
Resolution	W 8 dots/mm x H 16 dots/mm *2			
Paper feed pitch	0.03125 mm			
Maximum print speed	100 mm/s *3		80 mm/s *3	
Print width	48 mm		72 mm	
Paper width	$58^{\,0}_{-1}$ mm		$80^{\,0}_{-1}$ mm	
Thermal head temperature detection	Thermistor			
Platen position detection	Mechanical switch			
Out-of-paper detection	Reflection type photo interrupter			
Cutter home position detection	Transmission type photo interrupter			
Operating voltage range V_P line V_{DD} line	4.75 V to 9.5 V *4 2.7 V to 3.6 V, 4.75 V to 5.25 V		6.5 V to 9.5 V 2.7 V to 3.6 V, 4.75 V to 5.25 V	
Printer current consumption V_P line Thermal head drive Motor drive V_{PP} line Thermal head logic	5.49 A max. (at 9.5 V) *5 0.60 A max. 0.10 A max.		5.40 A max. (at 9.5 V) *5 0.60 A max. 0.10 A max	
Auto-cutter current consumption V_P line Motor driving	0.70 A max.			
Paper cutting method	Slide cutting			
Type of paper cutting	Full cut and partial cut (1.5 ±0.5 mm tab left at the center)			
Paper curling tendency	Fixed blade side and movable blade side			
Minimum paper core diameter	ϕ 8 mm			
Minimum paper cutting length	10 mm			
Cutting processing time	Approximately 1.0 s/cycle			
Cutting frequency	1 cut/2 s maximum			
Operating temperature range	-10°C to 50°C (non condensing)			

5.3 Printer Drive Motor and Thermal Head Drive Method

The printer drive motor and the thermal head must be driven at the same time for printing. The printer has half dot pitch thermal head, the pitch to the paper feed direction is one-half dot of the heat elements. Configure 1 dot by 2 half dots.

The motor feeds the thermal paper for 1 dot line by the 4 steps. It is necessary to feed the thermal paper 4 steps and activate the thermal head once every 2 steps, to configure the 1 dot line.

Figure 5 describes the drive method as an example of the CAPD245 and shows a timing chart for using fixed six divisions printing.

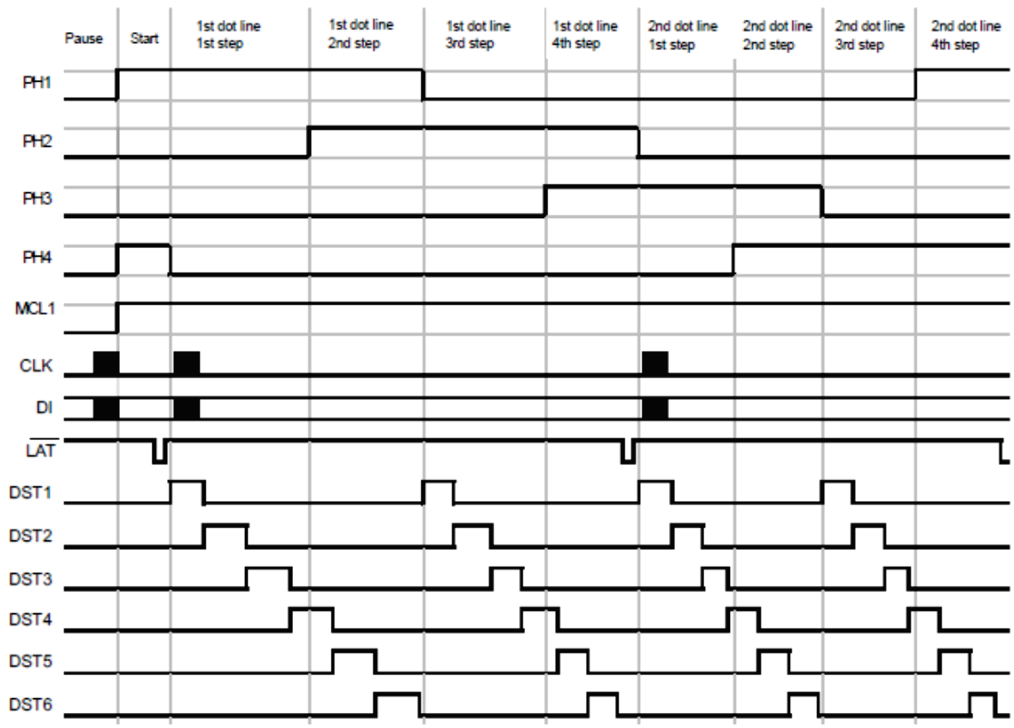

Figure 5. Timing Chart for Using Fixed Six Divisions Printing

5.4 Motor Driver Sections

The motor driver section is built around the DRV8834 dual-H-Bridge current-control motor driver ICs. It has a built-in Indexer logic with simple STEP/DIRECTION control and up to 1/32-step micro-stepping. Due to the availability of the indexer, the microcontrollers burden of driving the stepper motor in the printer mechanism is totally off-loaded. Rather than generating the appropriate pulses using four output lines, the microcontroller can now drive the stepper motor very easily using a single output line connected to the STEP pin of DRV8834. Through this single control line, the microcontroller sends square pulses to turn the motor as per the step size selected through the configuration pins in DRV8834. In this application, the DRV8834 is configured to operate in half-step mode for each square pulse sent through the STEP input.

The cutter stepper motor is also operated in the same way explained above for the printer stepper motor.

5.5 RS232 Communication From External Host Board

This board has a RS232 conversion section available for sending and receiving signals from an external host controller. This section is designed around the TI max3232 RS232 level converter.

There is also a provision for bypassing the rs232 converter IC section for connecting the TTL/CMOS level directly. This can be done by mounting the R23,24,25,26 zero Ω resistor option on the board.

5.6 Text Rendering and Data Transfer to the Printer Head

The main challenge in any thermal printer driver solution is the text rendering. Usually the text characters to be printed on the paper will come through one of the communication interface like UART or USB. The data received through the communication interface will be in ASCII format represented in 8-bit length. This data has to be written to the thermal paper in the actual form of the character it represents, which is called text rendering. A straight forward way to do this is to have a bitmap table stored inside the microcontroller Flash and pick the corresponding bitmap from the character table. But the drawback of this approach is the memory required to store the bit map tables.

Another innovative approach to address this issue is to use the bitmap tables in a compressed format. This can be done easily in TIVA controllers with the help of Stellarisware® or Tivaware software library. The compression and decompression of the bitmap is taken care of by the library. The application takes the output of the library functions and remaps it in such a way that it can be sent to the printer for a proper printing. All the required functions for doing the remapping is taken care of by the application code provided with this application report.

The application uses the library functions for un-compressing the characters from the compressed bitmap table. Then, the uncompressed character bitmaps are written to an internal memory location, which is considered as a two dimensional plane. From there, the characters are picked by the data transfer routine to send the bitmaps to the thermal printer head using an hardware SPI or an GPIO emulated SPI.

5.7 Temperature and Battery Monitoring

The battery voltage is fed to a resistor divider network and the voltage at the divider point is fed directly to the microcontroller ADC pin. The microcontroller captures multiple samples of this voltage and stores the information in the corresponding register for further use of the application.

The temperature of the printer head is measured using the built-in temperature sensor inside the printer mechanism. A voltage is applied to the internal thermistor through a 10K resistor on board. The junction of this external resistor and the internal thermistor is connected to the ADC pin of the microcontroller for measuring the instantaneous temperature of the printing head to avoid damage and optimizing the speed.

5.8 Push Button Operation

There are two push buttons provided on the board named as SW1 and SW2.

- Pressing SW1 automatically prints a logo of Texas Instruments.
- Pressing SW2 does the paper feed function.

Indicator LEDs

There are two indicator LEDs provided for displaying various status signals:

- Led 1 is the indication for 3.3 V power.
- Led 2 is the indication for any error. For example, paper roll not present.

6 Graphical User Interface

To enable the quick evaluation of the thermal printer solution, a graphical user interface (GUI) is also available along with this application. The GUI has developed using C# language from Microsoft. Using this GUI, its very easy to send and receive commands and data to and from the printer. The communication interface used here is the commonly available UART interface. All the built-in escape commands are available as a function in the GUI.

7 Thermal Printer Graphical Interface

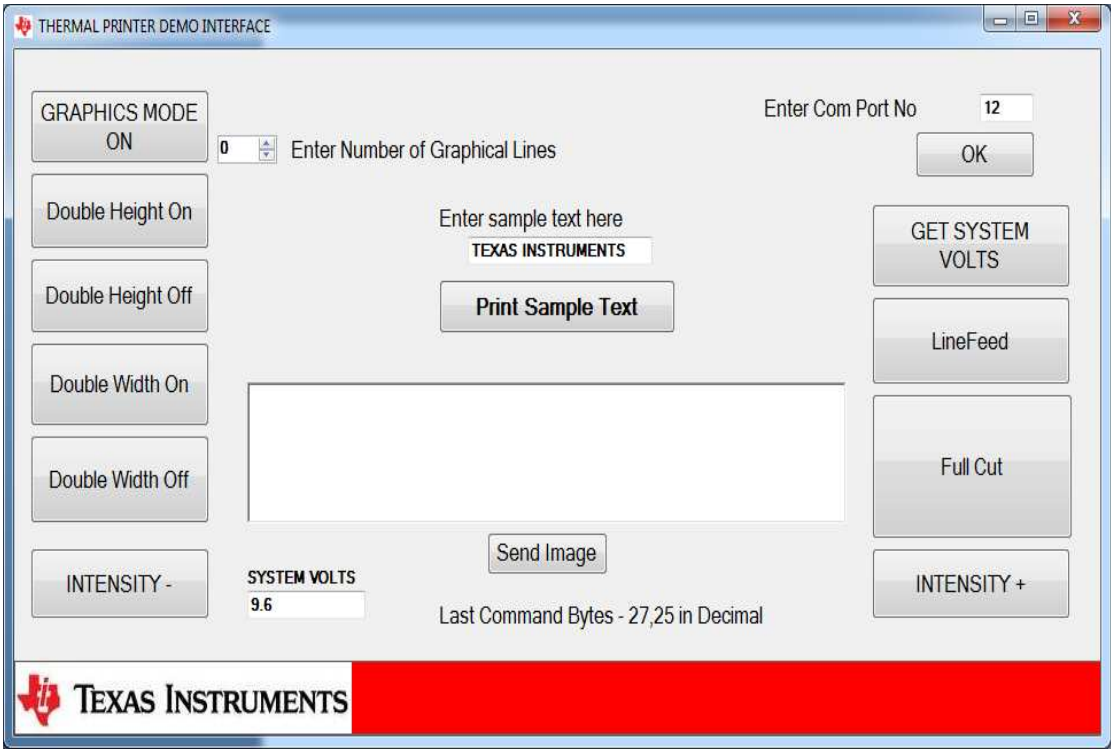

Figure 6. Thermal Printer Demo Interface

Figure 6 shows the GUI for the Tiva thermal printer demo. Using this GUI, you can print sample text from the comfort of a Windows-based PC . You can try various commands supported by the firmware by using this interface. It supports multiple commands like cutting, double height printing, image printing, and so forth. It also displays the command byte information it sent through the UART.

Before sending any commands, you have to select the appropriate com port number and enter it into the box given on the right hand top corner and press the OK button. If the port is free and usable, the software issues the message “PORT OPENED SUCCESSFULLY”. After this, you can start using the various command buttons.

7.1 Button 1 – Print Sample Text

This button enters sample text in the text box provided above the button to directly print on the paper. Enter the sample text and click on the “Print Sample Text” button.

7.2 Button 2 – Send Image

This button prints images through the uart channel. You can paste the graphics image data in the box provided above this button. The image box accepts the Stellarisware compatible C array of the image. You can directly copy and paste the Stellarisware compatible C array of the image and press the “Send Image” button. The software transfers the data in multiple blocks if the image size is more than 104 lines, which is equivalent to 5000 bytes of internal UART memory buffer.

7.3 Button 3 - GRAPHICS MODE ON

This button prints graphical data to the paper in a line-by-line basis. The number of lines of data to be printed at a single instance is selected from the pull down menu adjacent to this button. The value can range from 1 line to 255 lines. After the specified number of lines, the mode will automatically be transferred to text mode.

7.4 Button 4 – Double Height On

This button increases the height of the text printing. It will print the text in double size in height from normal.

7.5 Button 5 – Double Height Off

This button reduces the height of text printing to normal size. It will cancel the effect of “DOBLE HEIGHT ON” button.

7.6 Button 6 – Double Width On

This button increases the width of the text printing. It will print the text in double size in width from normal.

7.7 Button 7 – Double Width Off

This button reduces the width of text printing to normal size. It will cancel the effect of “DOBLE WIDTH ON” button.

7.8 Button 8 – INTENSITY +

This button increases the darkness (intensity) of the printing. Each press on this button increase the intensity by a small delta, which is equivalent to a delay of 1000 units of clock of the controller applied to thermal head energizing.

7.9 Button 8 – INTENSITY -

This button decreases the darkness (intensity) of the printing. Each press on this button decrease the intensity by a small delta, which is equivalent to a delay of 1000 units of clock of the controller applied to thermal head energizing.

7.10 Button 9 – Full Cut

This button operates the built-in cutter to perform a full cut operation.

7.11 Button 10 – LIne Feed

This button pushes the paper to approximately 10 cms for a demonstration purpose. This length can easily be adjusted in the firmware code.

7.12 Button 11 – GET SYSTEM VOLTS

This button collects the ADC value of the battery monitoring channel pin for implementing the intensity control loop from a host machine through commands. It returns the 12-bit value of the ADC in hex format.

Appendix A Schematic

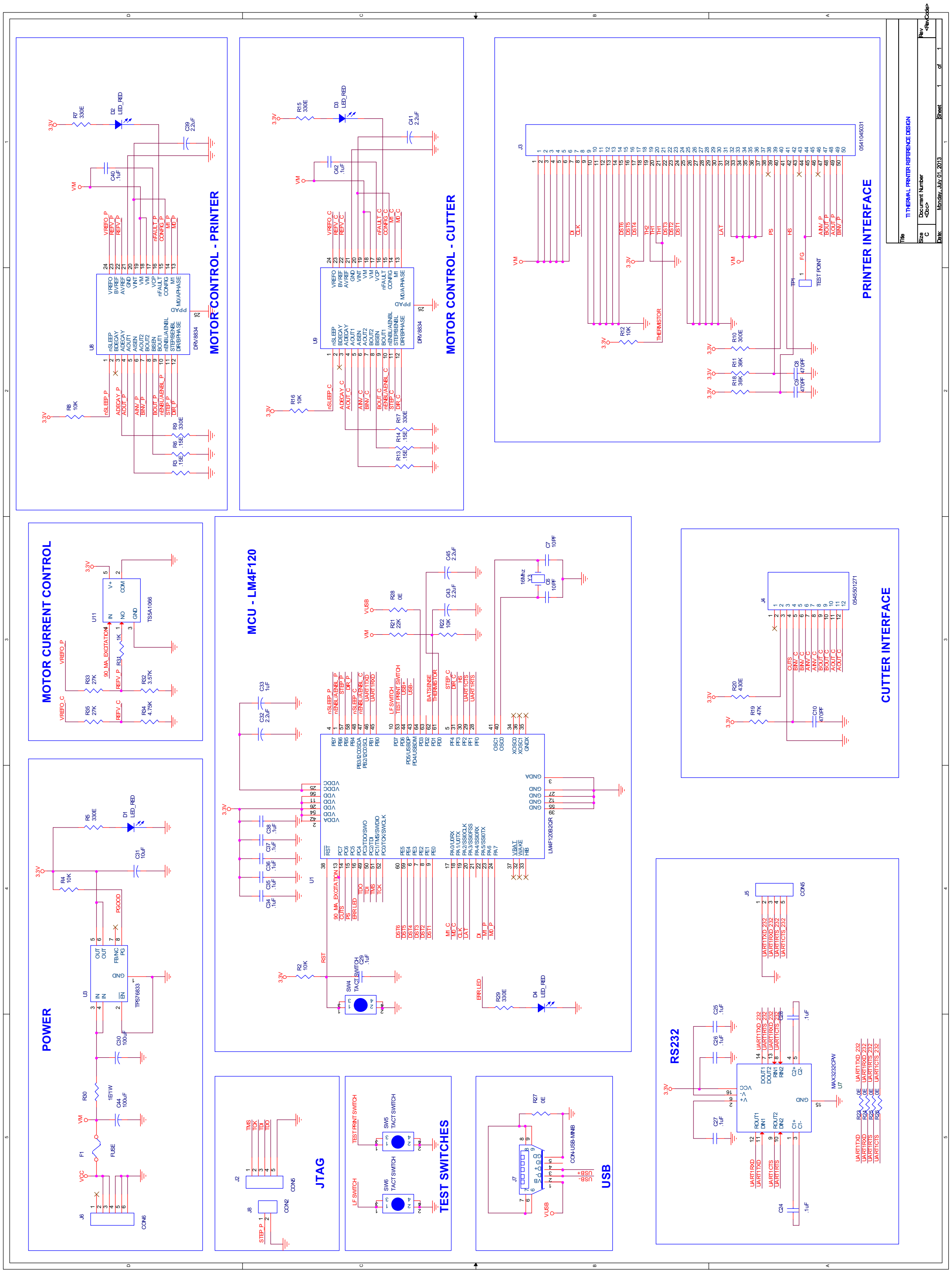

Figure 7. Schematic

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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