DEVELOPMENT OF A UNIVERSAL SERIAL HUB BUS WITH PROTECTION CIRCUITS

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Signature : ____________________________

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Date : 1 MAY 2008

To my mother, father, brothers and sister.

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Alhamdulillah,

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ABSTRACT

Objective of this project is to design, construct and develop a Universal Serial Bus (USB) hub with protection circuits. There are two types of USB hub according to their supplied power that is self powered USB hub and bus powered USB hub. Self powered USB hub means that USB hub get their power from power supply, and bus powered USB hub means that USB hub get their power from personal computer. This project only develops one type of USB hub which is self powered USB hub. In order to wider the scopes of this project, this project is added with powered circuits to make it more firm and hard to be blow out. The most important thing in designing this project is to manage input power and supply power for each port. Four ports are chose to be implementing in the circuits to be connecting into one personal computer. This project also will discuss the result in connecting four computer devices onto one personal computer using final and complete developed gadget

ABSTRAK

Objektif projek ini adalah untuk mereka, membentuk dan membina Universal Serial Bus (USB) hub dengan litar perlindungan. Terdapat dua jenis USB hub bergantung kepada tenaga yang diperolehinya iaitu USB hub dengan perolehan tenaga sendiri dan USB hub dengan perolehan tenaga angkutan. USB hub dengan tenaga perolehan sendiri bermaksud penerimaan tenaga oleh USB hub dari punca tenaga, manakala USB hub dengan perolehan tenaga angkutan bermaksud penerimaan tenaga oleh USB hub melalui komputer peribadi. Project ini hanya membina satu jenis USB hub iaitu USB hub dengan perolehan tenaga sendiri. Di dalam meluaskan skop projek ini, projek ini dilengkapkan dengan litar perlindungan untuk menjadikanya lebih lasak dan tidak mudah rosak. stepper motor bergantung kepada lilitan wayarnya iaitu unipolar dan bipolar. Perkara paling penting di dalam membina projek ini adalah mengawal tenaga masuk dan tenaga yang diberikan untuk setiap port. Empat port dipilih untuk disertakan di dalam litar untuk disambungkan kepada sebuah komputer peribadi. Projek ini juga membincangkan keputusan di dalam menyambungkan empat peralatan komputer kepada sebuah komputer peribadi menggunakan gadget akhir yang telah sempurna dibina.

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LIST OF ABBREVIATIONS

USB	- Universal Serial Bus
UMP	- Universiti Malaysia Pahang
DC	- Direct Current
AC	- Alternating Current
V	- Voltage
IC	- Integrated Circuit
EEPROM	- Electrically Erasable Programmable Read-Only Memory
VID	- Vendor Identical
PID	- Product Identical
DID	- Device Identical
R	- Resistor
C	- Capacitor
L	- Inductor
Vin	- Input Voltage
Vout	- Output Voltage

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CHAPTER 1

INTRODUCTION

This chapter will discuss on the term Universal Serial Bus (USB) and USB hub. The problem statement which contributes to the creation and development of this project, overview, objective and scope of this project is also presented in this chapter.

1.1 Overview

It seems nearly every electronic gadget manufactured today makes use of the ever-handy USB port. Early computers featuring USB normally had only one or two ports located inconveniently at the back of the case. Newer computers feature several built-in USB ports, and many cases now place two or more of these ports in front. Even so, additional ports are often needed, and having them conveniently accessible makes all the difference. The USB hub does just that.[1]

A USB hub is a small, light unit with multiple ports for plugging in USB devices. It is commonly connected to a USB port located on the back of a desktop computer by using an extension cable. Once the hub is plugged in, you can set it wherever is convenient, avoiding the hassle of accessing the rear of the system. A USB hub is also great for laptops with only one or two ports. Most hubs can support up to 127 devices.[1]

A self-powered USB hub can be used to connect digital cameras, card readers, keyboards, mice, MP3 players, memory sticks and many other handheld USB devices. For more robust components such as external drives, printers, scanners or fax machines, an AC-powered USB hub is a better choice. Some of the AC-powered hubs come with an AC-adapter, while others have the capability, but require the separate purchase of an adapter. [1]

Another feature to look for is 1.1 or 2.0 compliancy. This refers to the two versions of USB technology. USB 1.1 is capable of data transfer speeds up to 12 megabits per second (mbps), while USB 2.0 can transfer data at 480 mbps, 40x faster. Initial USB devices were engineered to use USB 1.1, while later devices took advantage of the newer 2.0 compliancy. [1]

A USB hub that supports 2.0 is often backwards compatible, supporting 1.1 devices as well. The hub automatically detects and runs at the fastest rate the device will support. A USB hub that supports 2.0 cannot "push" a 1.1 device to run faster than its design. Conversely, a hub that *only* supports 1.1 may or may not support a 2.0 device, but if it does, it will slow it down to 12 mbps —- the fastest speed the hub supports. [1]

Virtually all USB devices are *plug 'n' play*, or *hot-swappable*, but it's wise to be conservative with this feature when using an external hard drive with a USB port. Data could be lost due to software bugs or if the drive is unplugged while busy. [1]

A USB hub is an inexpensive, handy addition to any system, especially useful with laptops that normally have too few native USB ports and older systems that have rear ports. A USB hub can be purchased in a four-port model, a seven-port model, or greater. Multiple hubs can be used for scalable growth. [1]

1.2 Objective

The objectives of this project are stated below:

1.2.1 To transmit and receive data using USB controller.

This objective is desire a fully functional USB hub as the final product. This is the main objectives of the entire project. The USB hub also must be able to transmit and receive data between at least two devices and one computer.

1.2.2 To develop a protection circuits for USB hub.

The objective is to provide a protection circuits to the USB hub. Their first priority is to protect the USB controller and components that being use in transmitting and receiving data. The circuits should not fragile and must not require any circuit to protect it.

1.2.3 To make this project as reference to others in the future.

After a series of research, I have discovered that there is only limited information about Universal Serial Bus out there. The only mass information is about how to make and build it but there is no detail research. With this project, I could offer a reference to those who want to make this project in the future with detail information.

1.3 Scope of the Project

The scopes of this project can be divided in to two. First part is USB controller circuit, this circuit build based on basic data transfer circuits and consist of downstream ports, upstream port, data storage and USB controller IC. Second part of this scope is protection circuits, this circuit aim to make the USB circuit more firms.

Protection circuits consist, 5V voltage regulator, 3V voltage regulator, and power management circuit. Overall project required knowledge in:

- Microcontroller understanding
- Circuits fundamental theory
- PSpice software

1.4 Problem statement

The problem statements of this project are stated as below:

1.4.1 Insufficient Ports

During first year in UMP, I bought a laptop to be using in study. After few month I bough many computer devices as additional features to be add in to my computer such as webcam, printer, mouse, thumb drive and scanner. Because of this, I have insufficient USB ports on my computer to attach new computer devices.

1.4.2 Verification of Doubts

During my seventh semester at UMP, I have taken the course Engineering Projects 1 [BEE4712]. On this course, I've being given a choice to choose my topics as my project, one of the topic was to design a USB hub, at that time, I figure out my problem on my first year in UMP, due this problem I insist to take this topic and gaining knowledge in developing my own USB hub.

1.5 Thesis Organization

This thesis consists of five chapters including this chapter. The contents of each chapter are outlined as follows;

Chapter 2 contains a literature review that discussed about the types of elements that will be selected to be used in this project.

Chapter 3 is all about the project methodology. It is specified the method that used in this project in details. It also contains the application and how the testing circuit to be implemented. This will explain how this project is organized and the flow of the process in completing this project.

Chapter 4 presents about the result and discussion that comes from the output of the project. It is presented in phases that are categorized into two phases which are the actual and the simulation results.

The last chapter which is Chapter 5 contains of the conclusion and recommendations to the project. The several difficulties and solution also stated in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 USB hubs

Most computers that you buy today come with one or two USB sockets. With so many USB devices on the market today, you easily run out of sockets very quickly. For example, on the computer that I am typing on right now, I have a USB printer, a USB scanner, a USB Webcam and a USB network connection. My computer has only one USB connector on it, so the obvious question is, "How do you hook up all the devices?"[2]

The easy solution to the problem is to buy an inexpensive USB hub. The USB standard supports up to 127 devices and USB hubs are a part of the standard.

Figure 2.1: USB hub in the market.

A hub typically has four new ports, but may have many more. You plug the hub into your computer, and then plug your devices (or other hubs) into the hub. By chaining hubs together, you can build up dozens of available USB ports on a single computer. [2]

Hubs can be powered or unpowered. As you will see on the next page, the USB standard allows for devices to draw their power from their USB connection. Obviously, a high-power device like a printer or scanner will have its own power supply, but low-power devices like mice and digital cameras get their power from the bus in order to simplify them. The power (up to 500 milliamps at 5 volts) comes from the computer. [2]

If you have lots of self-powered devices (like printers and scanners), then your hub does not need to be powered -- none of the devices connecting to the hub needs additional power, so the computer can handle it. If you have lots of unpowered devices like mice and cameras, you probably need a powered hub. The hub has its own transformer and it supplies power to the bus so that the devices do not overload the computer's supply. [2]

2.1.1 Power

A bus-powered hub is a hub that draws all its power from the host computer's USB interface. It does not need a separate power connection. However, many devices require more power than this method can provide, and will not work in this type of hub. [3]

In contrast a self-powered hub is one that takes its power from an external power supply unit and can therefore provide full power to every port. Many hubs can operate as either bus powered or self powered hubs. [3]

USB current (related to power) is allocated in units of 100 mA up to a maximum total of 500 mA per port. Therefore a compliant bus powered hub can have no more than four downstream ports and cannot offer more than four 100 mA units of current in total to downstream devices (since one unit is needed for the hub itself). If more units of current are required by a device than can be supplied by the port it is plugged into, the operating system usually reports this to the user. [3]

However, there are many non-compliant hubs on the market which announce themselves to the host as self-powered despite really being bus-powered. Equally there are plenty of non-compliant devices that use more than 100 mA without announcing this fact (or indeed sometimes without identifying themselves as USB devices at all). These hubs and devices do allow more flexibility in the use of power (in particular many devices use far less than 100 mA and many USB ports can supply more than 500 mA before going into overload shut-off) but they are likely to make power problems harder to diagnose.[3]

Some powered hubs do not supply enough power to support a 500mA load on every port. For example, many 7 port hubs come with a 1A power adapter, when in fact seven ports could draw a maximum of 7 x 0.5 = 3.5A, plus power for the hub itself. The assumption is that the user will most likely connect many low power devices and only one or two requiring a full 500mA.[3]

2.1.2 Speed

To allow high-speed devices to operate in their fastest mode all hubs between the devices and the computer must be high-speed. High-speed devices should fall back to full-speed when plugged in to a full-speed hub (or connected to an older full-speed computer port). While high-speed hubs support all device speeds, low and full-speed traffic is combined and segregated from high-speed traffic through a transaction translator. Each transaction translator segregates lower speed traffic into its own pool, essentially creating a virtual full-speed bus. Some designs use a single transaction translator, while other designs have multiple translators. Having multiple translators is only a significant benefit when connecting multiple high-bandwidth full-speed devices. [3]

It is an important consideration that in common language (and often product marketing) USB 2.0 is used as synonymous with high-speed. However, because the USB 2.0 specification, which introduced high-speed, incorporates and supersedes the USB 1.1 specification, any compliant full-speed or low-speed device is still a USB 2.0 device. Thus, not all USB 2.0 hubs operate at high-speed. [3]

2.1.3 Physical layout

A USB network with many devices requires one or more hubs connected to each other. USB hubs can extend a USB network a maximum of five times. The USB specification requires that bus-powered hubs may not be connected in series to other bus-powered hubs. [3]

USB ports on computer housings are usually closely spaced, so that plugging devices into one port may block an adjacent port. This problem is shared by some, but not all, external USB hubs. Star-shaped hubs with each port pointing in a different direction, such as pictured top right, avoid this problem. Aside from practical layouts, novelty USB hubs have also been produced, such as one shaped like the TARDIS, a fictional time-traveling space ship from the BBC science fiction series *Doctor Who*, or another shaped like a nuclear missile launch console complete with a big red button (which shuts down the PC). [3]

Laptop computers may come with many USB ports built in, but a USB hub can consolidate several everyday devices (like a mouse and a printer) into a single port for quick attachment and removal. [3]

Also available are so-called "sharing hubs", which effectively are the reverse of a USB hub, allowing several PCs to access (usually) a single peripheral. They can either be manual (effectively a simple switch-box), or automatic, incorporating a mechanism that recognizes which PC wishes to use the peripheral and switches accordingly. They cannot grant both PCs access at once. Some models, however, have the ability to control multiple peripherals separately (e.g. 2 PCs and 4 peripherals, assigning access separately). Only the simpler switches tend to be automatic, and this feature generally places them at a higher price point too. [3]

2.1.4 Protocol

Each hub has exactly one upstream port and a number of downstream ports. The upstream port connects the hub (directly or through other hubs) to the host. Other hubs or devices can be attached to the downstream ports.

During normal transmission, hubs are essentially transparent: data received from its upstream port is broadcast to all devices attached to its downstream ports; data received from a downstream port is generally forwarded to the upstream port only. This way, what is sent by the host is received by all hubs and devices, and what sent by a device is received by the host but not by the other devices (an exception is resume signaling). [3]

Hubs are not transparent when dealing with changes in the status of downstream ports such as insertion or removal of devices. In particular, if a downstream port of a hub changes status, this change is dealt with an interaction between the host and this hub; the hubs between them act as transparent in this case. [3]

To this aim, each hub has a single interrupt endpoint "1 IN" (endpoint address 1, hub-to-host direction) used to signal changes in the status of the downstream ports. When a device is attached, the hub detects the device pull-up resistor on either D+ or D- and signals the insertion to the host via this interrupt endpoint. When the host polls this interrupt endpoint, it is informed of the presence of the new device. It then instructs the hub (via the default control pipe) to reset the port where the new device is connected. This reset makes the new device assuming address 0, and the host can then interact with it directly; this interaction will result in the assignment of a new (non-zero) address to the device. [3]

2.1.5 Electronics design

Most USB hubs use one or more integrated controller ICs, of which several designs are available from various manufacturers. Most support a four port hub system, but hubs using seven-port hub controllers are also available. Additional features on some hub controllers include control of port LED (sometimes automatic, sometimes under control of the host PC) and PS/2 to USB conversion for mice and keyboards. [3]

2.2 USB hub design

USB hubs can be built that operate in either self-powered or bus-powered mode. Self-powered hubs draw their power from the electrical outlet, while bus-powered hubs draw their power from the USB bus. From the aspect of user experience, hubs operating in self-powered mode have a significant advantage over hubs operating in bus-powered mode for the following reasons:

- A user can plug any bus-powered USB device into any port on a self-powered hub, and the device will always have enough power to function. The power needed by a bus-powered USB device in order to function can range from a few mA up to a maximum of 500mA.

- A user can plug a bus-powered USB device into a port on a bus-powered hub, but the device might not have enough power to function. Specifically:
    - Only low-power bus-powered devices are guaranteed to have enough power available from a bus-powered hub port to operate. Low-power bus-powered devices draw less than 100mA when fully operational. To meet the specification, a bus-powered hub must supply up to 100mA at each port, but must not supply more than 100mA. Typical low-power bus-powered USB devices include mice, keyboards, and other HID devices.
    - A large number of USB devices require between 100mA and 500mA from the hub port when fully operational. These devices will not operate when the user plugs them into a port on a bus-powered hub. Examples of high-power bus-powered devices that will not work with a bus-powered hub include video cameras, page scanners, and floppy disk drives.

Even if it seems unlikely that a user would use USB for a high-power device, the problem with bus-powered USB hub designs is the user's expectation that *any* USB device can be plugged into *any* hub and it will work. This is not true with bus-powered hub designs. [4]

2.3 Windows operating system.

High-power, bus-powered devices can draw up to 500mA after they are configured by host system software, but must not draw more than 100mA until they are configured. The device circuitry and self-descriptive information that the host system software requires to enumerate the device are available to the host in this low-power mode. [4]

If the user who is running Microsoft Windows 98 plugs a high-power bus-powered device into a port on a bus-powered hub, the device will not work - and little information will be available to help the user understand why. Windows 98 shows the device as disabled in Device Manager, but does not warn the user with a message, for example, at the time of the hot-plug event. [4]

Windows 98 Second Edition, Windows Me, Windows 2000, and Windows XP give the user more help in such a situation. The device is shown as disabled in Device Manager and the user is also presented with a message that indicates why the device is not operating. However, it is still up to the user to locate an unused port on the PC platform or on a self-powered hub connected to the PC platform. Then the user must disconnect the high-power bus-powered device from the bus-powered hub and reconnect it to a port that will supply enough power. [4]

2.4 .HEX calculation

Intel 8-bit Hex File Format is the most common hex file format used in the world as far as I know. There is also Motorola Hex file format and maybe other. Creating applications with AVR-GCC we usually select ihex output file format what means Intel hex file format. [5]

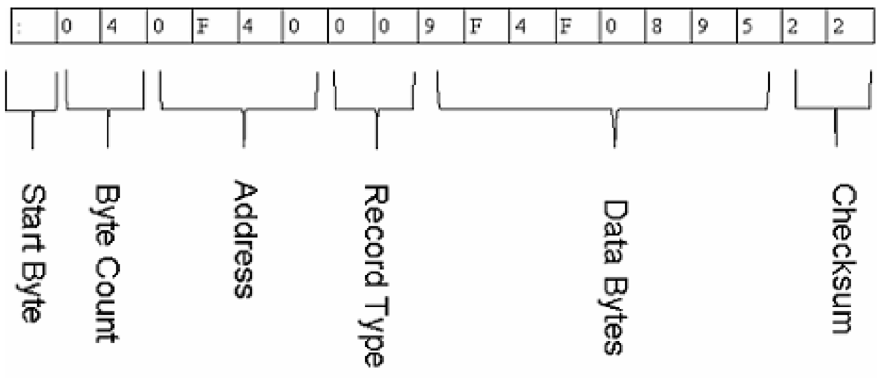


Figure 2.2: .HEX format

Position	Description
1	Record Marker: The first character of the line is always a colon(ASCII 0x3A) to identify the line as an Intel Hex file
2 – 3	Record Length: This field contains the number of data bytes in the register represented as a 2-digit hexadecimal number. This is neither the total number of data bytes, not including the checksum byte nor the first 9 character of line.
4 – 7	Address: This field contains the address where the data should be loaded into the chip. This is a value from 0 to 65,535 represented as a 4-digit hexadecimal value.
8 – 9	Record Type: This field indicates the type of record for this line. The possible values are: 00=Register contains normal data, 01=End of file; it is usually ":00000001FF", 02=Extended address.
10 - ?	Data Bytes: The following bytes are the actual data that will be burned into the EEPROM. The data is representing as 2-digit hexadecimal values.
Last 2 Character	Checksum: The last two characters of the line are checksum for the line. The checksum value is calculated by taking the two's compliment of sum of all the preceding data bytes, excluding the checksum byte itself and the colon at the beginning of the line.

Table 2.1: Description of .HEX bytes

Check sum calculation example:

:040F40009F4F089522

Taking all the data bytes above, we have to calculate the checksum based on the following hexadecimal values:

04+0F+40+00+9F+4F+08+95 = 1DE

The value is greater then we leave part which is less than FF,so we get DE.

Then Twos complement is 100h-DE=22

[5]

In Intel Hex File Format there are six types of record types:

- 00 – data record;
- 01 – End of file record. Usually it is ":00000001FF";
- 02 – Extended Segment address record. This indicates segment base address when 16 bits is not enough for addressing memory;
- 03 – Start segment address record. Indicates initial segment base address.
- 04 – Extended Linear Address Record – allows 32 bit addressing.
- 05 – Start Linear Address Record.

[5]

CHAPTER 3

METHODOLOGY

3.1 Project Overview

This project only involves hardware. The hardware can be divided into two parts which is USB controller and USB protection circuit. USB controller circuit can be divided into four stages which are the downstream ports, upstream ports, USB controller IC and SPI serial EEPROM. USB protection circuit can be divided into three stages which are 5V voltage regulator, 3V voltage regulator and power management circuit. When all the circuit is functioning and have the desired output, the circuits will be integrated into one massive functioning circuit.

3.2 Hardware explanations

3.2.1 USB controller circuit

USB controller circuits consist of four stages which are downstream ports, upstream port, SPI serial EEPROM and USB controller IC.

3.2.1.1 Downstream port circuit

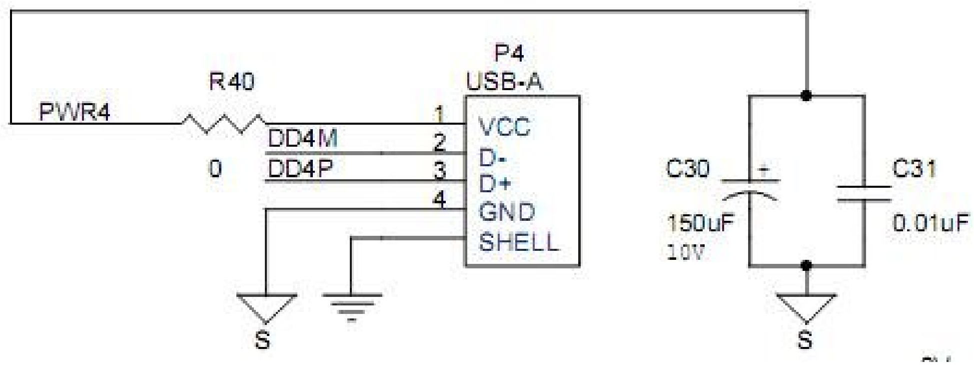


Figure 3.1: Basic downstream circuit

Downstream port is the place to plugging in computer device plug into the hub. Downstream circuit shown in figure 3.1 above describe how downstream port be attaching into hub. Downstream D+ and D– pull-down resistors are incorporated in USB controller for each port. Prior to the hub being configured, the ports are driven SE0 (Single Ended Zero, where both D+ and D– are driven LOW) and are set to the unpowered state. Once the hub is configured, the ports are not driven, and the host may power the ports by sending a “SetPortPower” command to each port. After a port is powered, any connect or disconnect event is detected by the hub. Any change in the port state is reported by the hub back to the host through the Status Change Endpoint (endpoint 1). Upon receipt of “SetPortReset” command from the host, the hub will

- Drive SE0 on the corresponding port
- Put the port in an enabled state
- Enable the green port indicator for that port
- •Enable babble detection once the port is enabled.

Babble consists of either unterminated traffic from a downstream port (or loss of activity), or a non-idle condition on the port after EOF2. If babble is detected on an enabled port, that port will be disabled. A ClearPortEnable command from the host will also disable the specified port. Downstream ports can be individually suspended by the host with the SetPortSuspend command.

If the hub is not suspended, any resume will be confined to that individual port and reflected to the host through a port change indication in the Hub Status Change Endpoint. If the hub is suspended, a resume on this port will be forwarded to the host, but other resume events will not be seen on that port. The host may resume the port by sending a ClearPortSuspend command.

3.2.1.2 Upstream port circuit

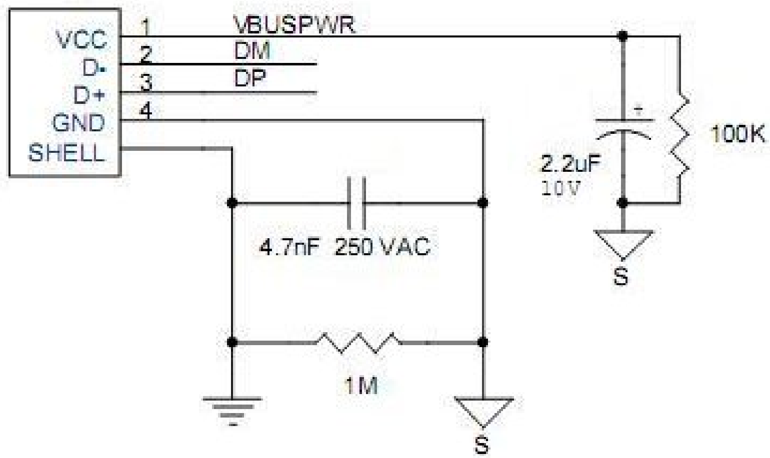


Figure 3.2: Basic upstream circuit

The upstream port includes the transmitter and the receiver state machine. The Transmitter and Receiver operate in high-speed and full-speed depending on the current hub configuration. The transmitter state machine monitors the upstream facing port while the Hub Repeater has connectivity in the upstream direction.

This monitoring activity prevents propagation of erroneous indications in the upstream direction. In particular, this machine prevents babble and disconnects events on the downstream facing ports of this hub from propagating and causing the hub to be disabled or disconnected by the hub to which it is attached. This allows the Hub to only disconnect the offensive port on detecting babble from it.

3.2.1.3 SPI serial EEPROM data storage

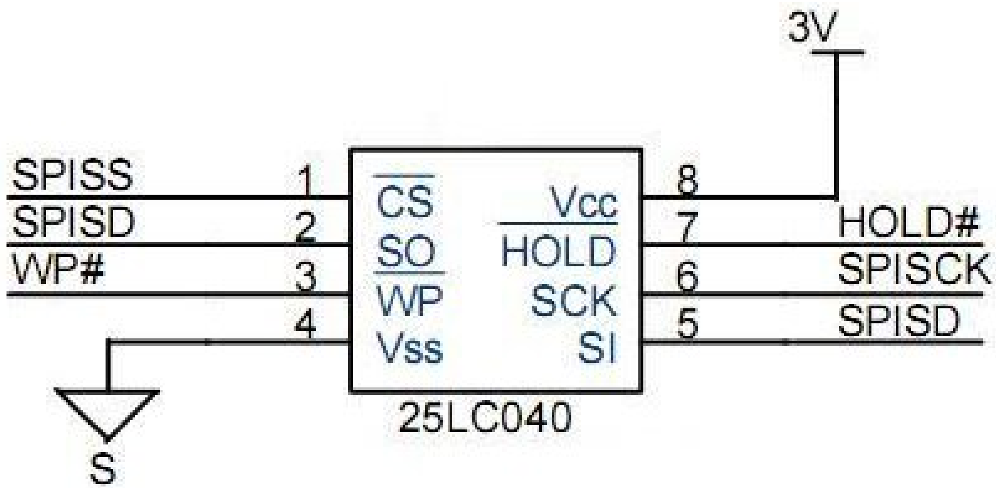


Figure 3.3: Basic PSI serial EEPROM circuit

Systems using USB controller IC must have an external EEPROM in order for the device to have a unique VID, PID, and DID. The USB controller IC can talk to SPI EEPROM that are double byte addressable only. USB controller IC uses the command format from the '040 parts. The USB controller IC cannot talk to ‘080 EEPROM parts, as the read command format used for talking to ‘080 is not the same as ‘040. The '010s and '020s uses the same command format as used to interface with the ‘040 and hence these can also be used to interface with the USB controller IC.

When used in default mode, only a unique VID, PID, and DID must be present in the external SPI EEPROM. The contents of the EEPROM must contain this information in the following format:

Byte	Value
0	00
1	00
2	00
3	00
4	00
5	00
6	00

Table 3.1: Data storage default Byte configuration

Byte	Value (MSB->LSB)
0	D2
1	B4
2	04
3	60
4	65
5	07
6	00
7	88
8	FF
9	32
10	64
11	32
12	81

Table 3.2: Data storage configured Byte configuration

Bytes descriptions

Byte 0: 0xD2

Needs to be programmed with 0xD2

Byte 1: VID (LSB)

Least Significant Byte of Vendor ID

Byte 2: VID (MSB)

Most Significant Byte of Vendor ID

Byte 3: PID (LSB)

Least Significant Byte of Product ID

Byte 4: PID (MSB)

Most Significant Byte of Product ID

Byte 5: DID (LSB)

Least Significant Byte of Device ID

Byte 6: DID (MSB)

Most Significant Byte of Device ID

Byte 7: EnableOvercurrentTimer[3:0], DisabledOvercurrentTimer[3:0]

Count time in ms for filtering overcurrent detection. Bits 7–4 are for an enabled port, and bits 3–0 are for a disabled port. Both range from 0 ms to 15 ms.

Byte 8: ActivePorts[3:0], RemovablePorts[3:0]

Bits 7–4 are the ActivePorts[3:0] bits that indicates if the corresponding port is usable. For example, a two-port hub that uses ports 1 and 4 would set this field to 0x09. The total number of ports reported in the Hub Descriptor: bNbrPorts field is calculated from this. Bits 3–0 are the Removable- Ports [3:0] bit that indicates whether the corresponding port is removable (set to HIGH). This bit's values are recorded appropriately in the HubDescriptor:DeviceRemovable field. Default: 0xFF.

Byte 9: MaximumPower

MaxPower field and is the current in 2-mA intervals that is required from the upstream hub.

Byte 10: HubControllerPower

HubContrCurrent field and is the current in milliamperes required by the hub controller. Default: 0x64 = 100 mA.

Byte 11: PowerOnTimer

PwrOn2PwrGood field and is the time in 2-ms intervals from the SetPortPower command until the power on the corresponding downstream port is good.

Byte 12: IllegalHubDescriptor, Unused, FullspeedOnly, NoPortIndicators, Reserved, GangPowered, SingleT-TOnly, NoEOPatEOF1

- **Bit 7**: IllegalHubDescriptor: For GetHubDescriptor request, some USB hosts use a DescriptorTypeof 0x00 instead of HUB_DESCRIPTOR, 0x29. According to the USB 2.0 standard, a hub must treat this as a Request Error, and STALL the transaction accordingly (USB 2.0, 11.24.2.5). For systems that do not accept this, the IllegalHubDescriptor configuration bit may be set to allow TetraHub to accept a DescriptorType of 0x00 for this command. Recommended setting is 1.
- **Bit 6**: Unused: This bit is an unused, don't care bit and can be set to anything.
- **Bit 5**: Fullspeed: Only configures the hub to be a full-speed only device. Default set to 0.
- **Bit 4**: NoPortIndicators: Turns off the port indicators and does not report them as present in the HubDescriptor, wHubCharacteristics b7 field. Default set to 0.
- **Bit 3**: Reserved: This bit is reserved and should not be set to 1. Must be set to 0.
- **Bit 2**: GangPowered: Indicates whether the port power switching is ganged (set to 1) or per-port (set to 0). This is reported in the HubDescriptor, wHubCharacteristics field, b4, b3, b1, and b0. Default set to 0.
- **Bit 1**: SingleTTOnly: Indicates that the hub should only support single Transaction Translator mode. This changes various descriptor values. Default set to 0.

- **Bit 0**: NoEOPatEOF1 turns off the EOP generation at EOF1 in full-speed mode. Note that several USB 1.1 hosts can not handle EOPatEOF1 properly. Cypress recommends that this option be turned off for general-purpose hubs. Default is 0, recommended setting is 1.

```
:020000020000FC
:0D000000D2B4046065070088FF32643281CD
:00000001FF
```

Figure 3.4: .HEX Data in EEPROM

Calculating the Checksum

As mentioned in the format table above, the last two characters represent a checksum of the data in the line. Since the checksum is a two-digit hexidecimal value, it may represent a value of 0 to 255, inclusive.

The checksum is calculated by summing the value of the data on the line, excluding the leading colon and checksum byte itself, and taking its two's complement. The line:

:020000020000FC

Breaking this line into it's components we have:

Record Length: 02 (2 bytes of data)

Address: 0000 (the 2 bytes will be stored at 0000, and 0001)

Record Type: 02 (Extended address data)

Data: 00, 00.

Checksum: FC

Taking all the data bytes above, we have to calculate the checksum based on the following hexidecimal values:

02+02 = 04

The two's complement of 04 is FC which is, as you can, the checksum value.

:0D000000D2B4046065070088FF32643281CD

Breaking this line into it's components we have:

Record Length: 0D (13 bytes of data)

Address: 0000 (the 13 bytes will be stored at 0000 till 1101)

Record Type: 00 (normal address data)

Data: D2,B4,04,60,65,07,00,88,FF,32,64,32,81.

Checksum: CD

Taking all the data bytes above, we have to calculate the checksum based on the following hexadecimal values:

D2+B4+04+60+65+07+00+88+FF+32+64+32+81= 33

The two's complement of 33 is CD which is, as you can, the checksum value.

3.2.1.4 USB controller IC

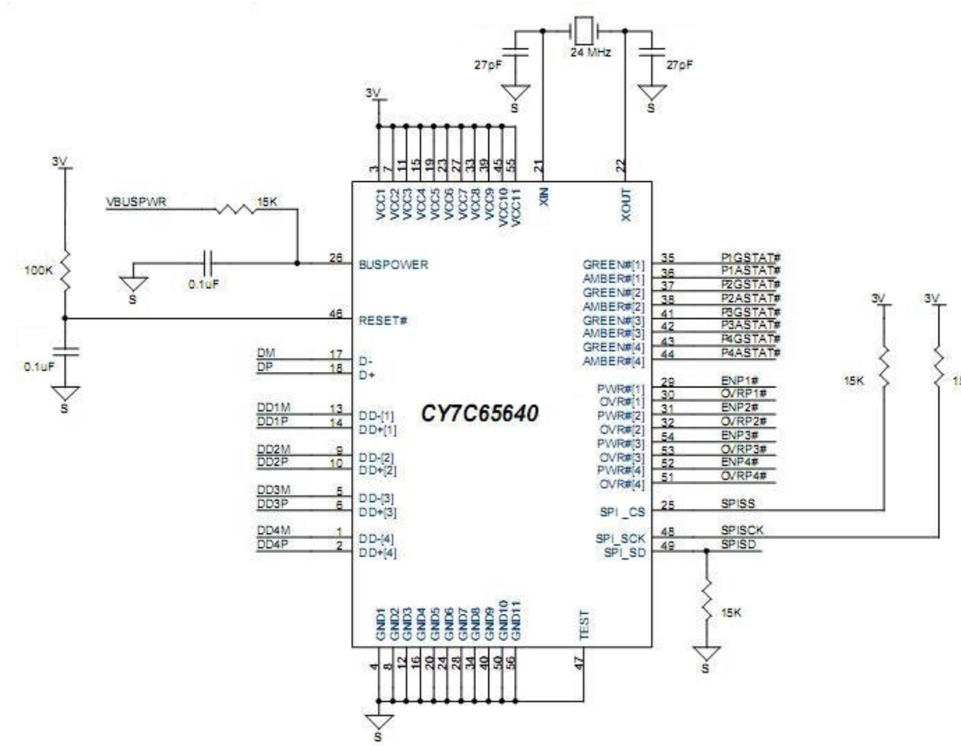


Figure 3.5: Basic USB controller IC circuit

USB controller IC is a high-performance self-powered Universal Serial Bus (USB) 2.0 hub. The Tetra architecture provides four downstream USB ports, with a Transaction Translator (TT) for each port, making it the highest-performance hub possible. This single-chip device incorporates one upstream and four downstream USB transceivers, a Serial Interface Engine (SIE), USB Hub Controller and Repeater, and four TTs. It is suitable for standalone hubs, motherboard hubs, and monitor hub applications. Being a fixed-function USB device, there is no risk or added engineering effort required for firmware development. We do not need to write any firmware for their design.

3.2.2 Protection circuits

The protection circuits consist of three stages which are 5V voltage regulator, 3V voltage regulator and power management circuit.

3.2.2.1 3V voltage regulator

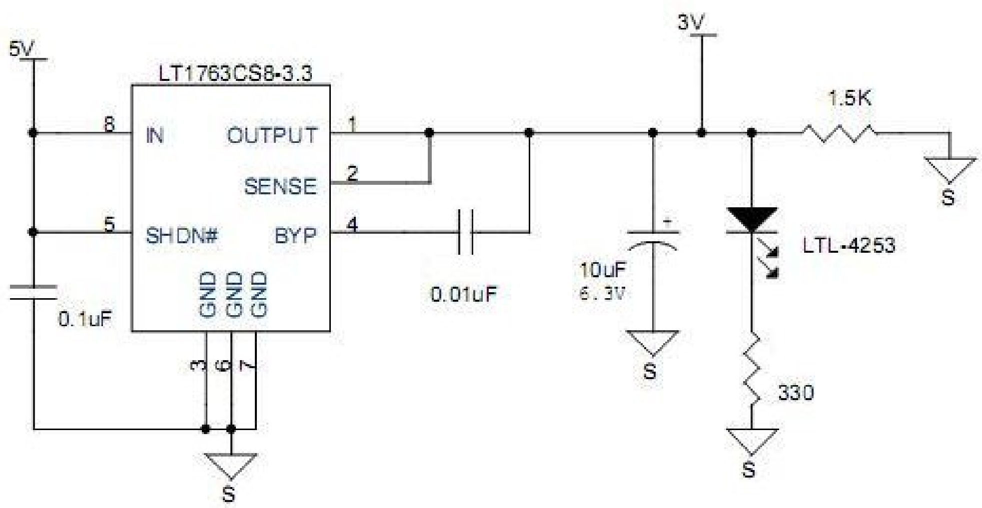


Figure 3.6: Basic 3V voltage regulator circuit

LT1763-3.3 is 3v voltage regulator that being chosen. The LT 1763 series are micro power, low noise, low dropout regulators. The devices are capable of supplying 500mA of output current with a dropout voltage of 300mV. Designed for use in battery-powered systems, the low 30µA quiescent current makes them an ideal choice. Quiescent current is well controlled; it does not rise in dropout as it does with many other regulators. A key feature of the LT1763 regulators is low output noise.

With the addition of an external 0.01µF bypass capacitor, output noise drops to 20µV over a 10 Hz to 100 kHz RMS bandwidth. The LT1763 regulators are stable with output capacitors as low as 3.3µF. Small ceramic capacitors can be used without the series resistance required by other regulators. Internal protection circuitry includes reverse battery protection, current limiting, thermal limiting, and reverse current protection. The parts come in fixed output voltages of 1.5V, 1.8V, 2.5V, 3V, 3.3V and 5V, and as an adjustable device with a 1.22V reference voltage.

3.2.2.2 Power management

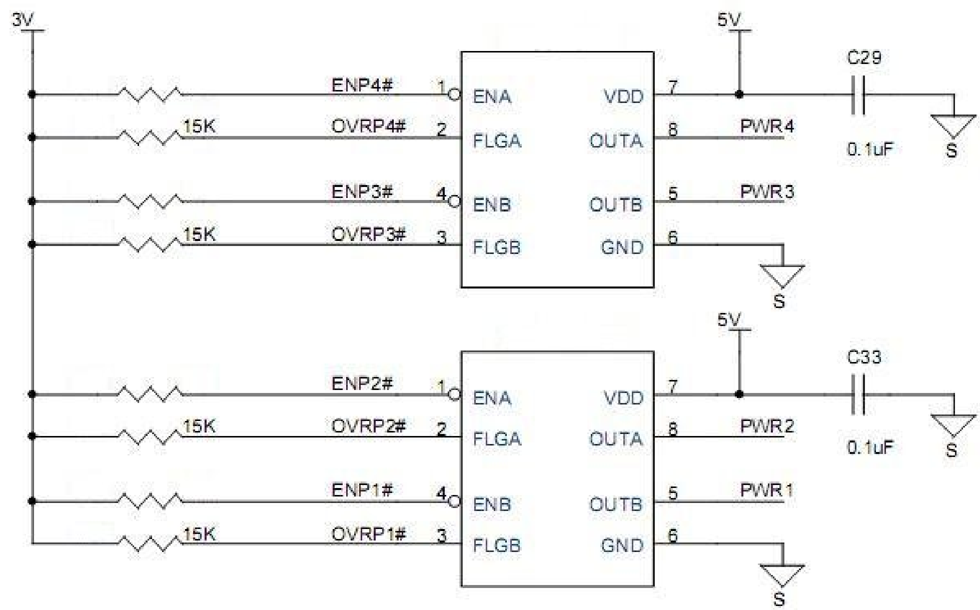


Figure 3.7: Basic Power management circuit

TheLM3526 power management provides Universal Serial Bus standard power switch and over current protection for all host port applications. The dual port device is ideal for Notebook and desktop PC's that supply power to more than one port.

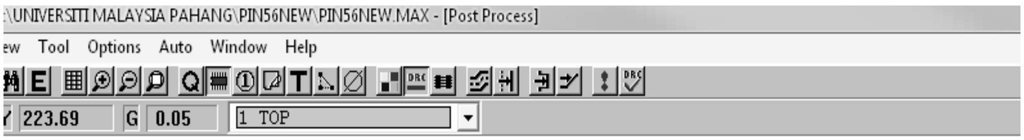
A 1ms delay on the fault flag output prevents erroneous over current reporting caused by in rush currents during hot plug events. The dual-stage thermal protection circuit, in the LM3526 provides individual protection to each switch and the entire device. In a short circuit / over-current event, the switch dissipating excessive heat is turned off, allowing the second switch to continue to function uninterrupted.

The LM3526 accepts an input voltage between 2.7V and 5.5V allowing uses as a device-based in-rush current limiter for 3.3V USB peripherals, as well as Root and Self-Powered Hubs at 5.5V. The Enable inputs accept both 3.3V and 5.0V logic thresholds. , and 1ms fault flag delay make the small size, low R ON LM3526 a good choice for root hubs as well as per-port power control in embedded and stand-alone hubs.

3.3 Self made base using PSpice software

In order to attaching few components into the circuit, based for the IC is required. Due to unavailable IC base in the market, self made base is created using PSpice and PCB machine.

3.3.1 Designing USB controller IC's base.



Plot output File Name	Batch Enabled	Device	Shift	Plot Title
*.TOP	No	EXTENDED GERBER	No shift	Top Layer
*.BOT	Yes	EXTENDED GERBER	No shift	Bottom Layer
*.GND	No	EXTENDED GERBER	No shift	Ground Layer
*.PWR	No	EXTENDED GERBER	No shift	Power Layer
*.IN1	No	EXTENDED GERBER	No shift	Inner Layer 1
*.IN2	No	EXTENDED GERBER	No shift	Inner Layer 2
*.IN3	No	EXTENDED GERBER	No shift	Inner Layer 3
*.IN4	No	EXTENDED GERBER	No shift	Inner Layer 4
*.IN5	No	EXTENDED GERBER	No shift	Inner Layer 5
*.IN6	No	EXTENDED GERBER	No shift	Inner Layer 6
*.IN7	No	EXTENDED GERBER	No shift	Inner Layer 7
*.IN8	No	EXTENDED GERBER	No shift	Inner Layer 8
*.IN9	No	EXTENDED GERBER	No shift	Inner Layer 9
*.I10	No	EXTENDED GERBER	No shift	Inner Layer 10
*.I11	No	EXTENDED GERBER	No shift	Inner Layer 11
*.I12	No	EXTENDED GERBER	No shift	Inner Layer 12
*.SMT	No	EXTENDED GERBER	No shift	Soldermask Top
*.SMB	No	EXTENDED GERBER	No shift	Soldermask Bottom
*.SPT	No	EXTENDED GERBER	No shift	Solder Paste Top
*.SPB	No	EXTENDED GERBER	No shift	Solder Paste Bottom
*.SST	No	EXTENDED GERBER	No shift	Silkscreen Top
*.SSB	No	EXTENDED GERBER	No shift	Silkscreen Bottom
*.AST	No	EXTENDED GERBER	No shift	Assembly Top
*.ASB	No	EXTENDED GERBER	No shift	Assembly Bottom
*.DRD	Yes	EXTENDED GERBER	No shift	Drill Drawing

Figure 3.8: PSpice setting for designing USB controller IC base

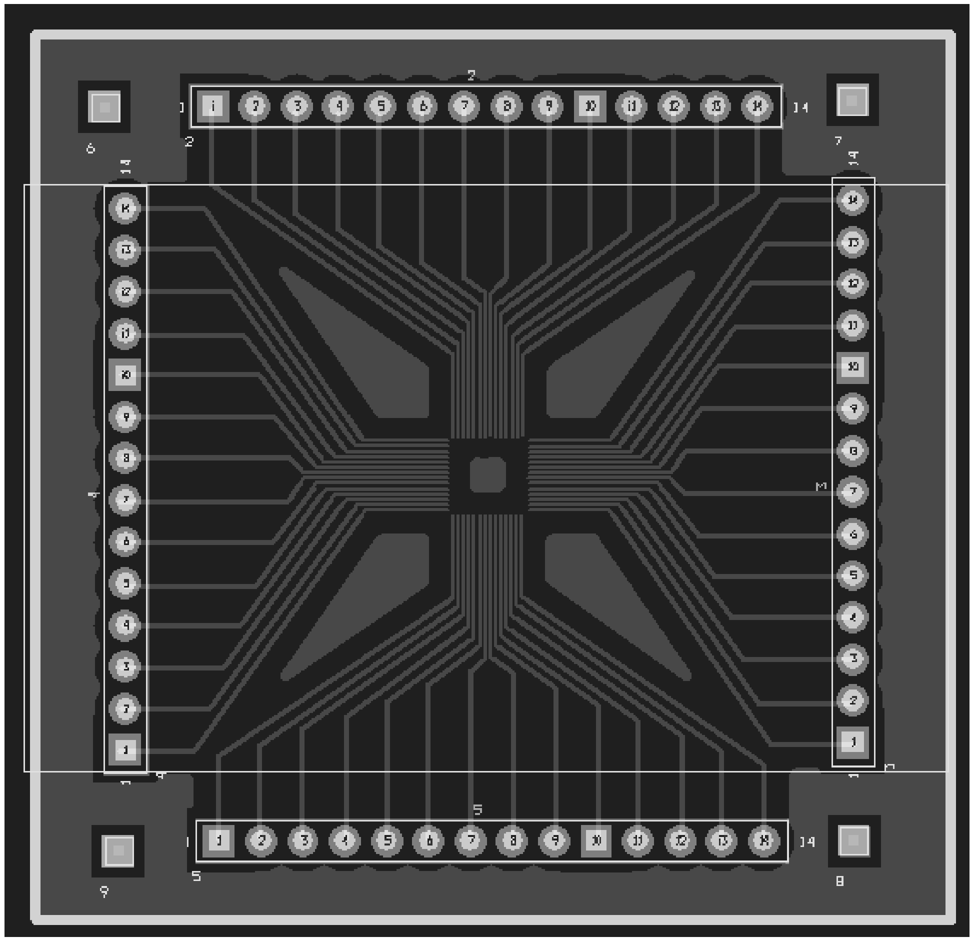


Figure 3.9: Complete design of USB controller IC base

3.3.2 Designing 3V voltage regulator IC, and power management IC's base.

Plot output File Name	Batch Enabled	Device	Shift	Plot Title
*.TOP	No	GERBER RS-274D	No shift	Top Layer
*.BOT	Yes	GERBER RS-274D	No shift	Bottom Layer
*.GND	No	GERBER RS-274D	No shift	Ground Layer
*.PWR	No	GERBER RS-274D	No shift	Power Layer
*.IN1	No	GERBER RS-274D	No shift	Inner Layer 1
*.IN2	No	GERBER RS-274D	No shift	Inner Layer 2
*.IN3	No	GERBER RS-274D	No shift	Inner Layer 3
*.IN4	No	GERBER RS-274D	No shift	Inner Layer 4
*.IN5	No	GERBER RS-274D	No shift	Inner Layer 5
*.IN6	No	GERBER RS-274D	No shift	Inner Layer 6
*.IN7	No	GERBER RS-274D	No shift	Inner Layer 7
*.IN8	No	GERBER RS-274D	No shift	Inner Layer 8
*.IN9	No	GERBER RS-274D	No shift	Inner Layer 9
*.I10	No	GERBER RS-274D	No shift	Inner Layer 10
*.I11	No	GERBER RS-274D	No shift	Inner Layer 11
*.I12	No	GERBER RS-274D	No shift	Inner Layer 12
*.SMT	No	GERBER RS-274D	No shift	Soldermask Top
*.SMB	No	GERBER RS-274D	No shift	Soldermask Bottom
*.SPT	No	GERBER RS-274D	No shift	Solder Paste Top
*.SPB	No	GERBER RS-274D	No shift	Solder Paste Bottom
*.SST	No	GERBER RS-274D	No shift	Silkscreen Top
*.SSB	No	GERBER RS-274D	No shift	Silkscreen Bottom
*.AST	No	GERBER RS-274D	No shift	Assembly Top
*.ASB	No	GERBER RS-274D	No shift	Assembly Bottom
*.DRD	Yes	GERBER RS-274D	No shift	Drill Drawing
*.FAB	No	GERBER RS-274D	No shift	Fabrication Drawing

Figure 3.10: PSpice setting for designing 3V voltage regulator and power management IC base

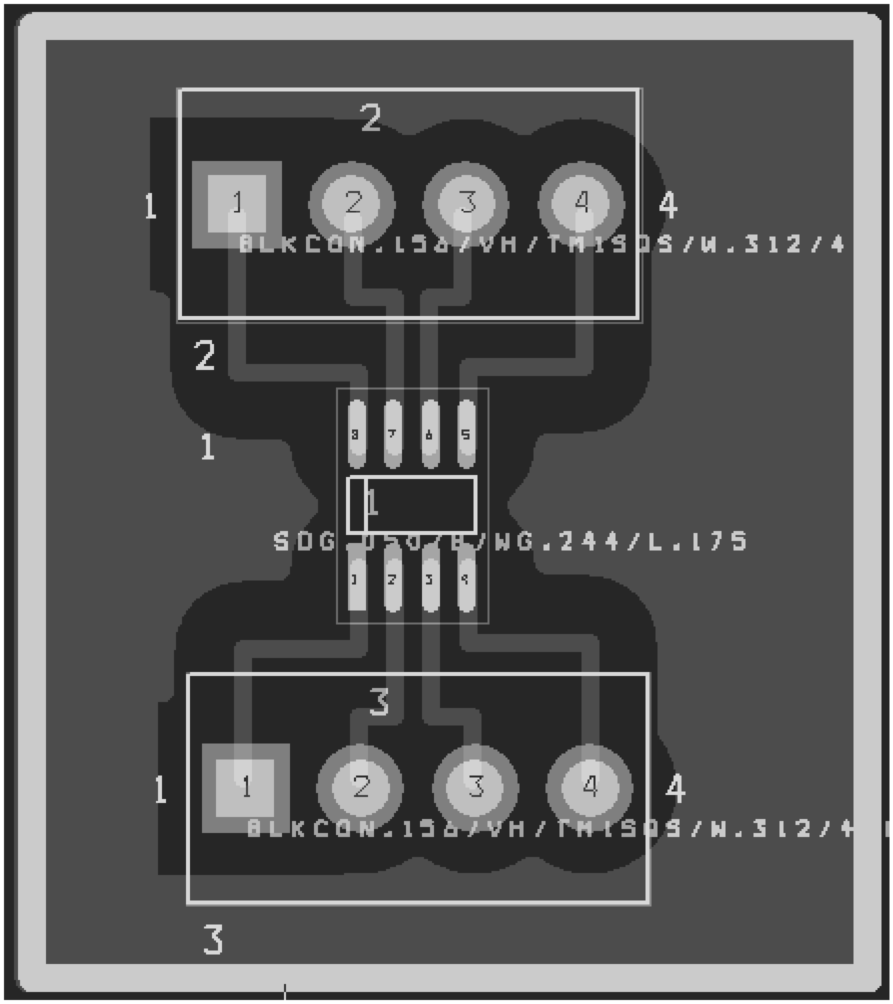


Figure 3.11: Complete design of 3V voltage regulator and power management IC base.

CHAPTER 4

RESULT AND DISCUSSION

4.1 USB controller circuit

The result that been taken by observing the computer when the device is connected, at the time device is connected, the new USB device icon appear on personal computer monitor. This approve that the USB controller circuits is functioning and can be detected on computer. But there was a problem occurs when the data cannot be transmitting due to unrecognized device by computer.

Figure 4.1: the new USB device icon appear

4.2 3V voltage regulator

In order to see the result for 3V regulator, two ways of observations being taken in the lab, the result show that with 3V voltage regulator, the waveform with noise is reduce and eliminated. This show that 3V voltage regulator is necessary in protecting input voltage for USB hub circuits.

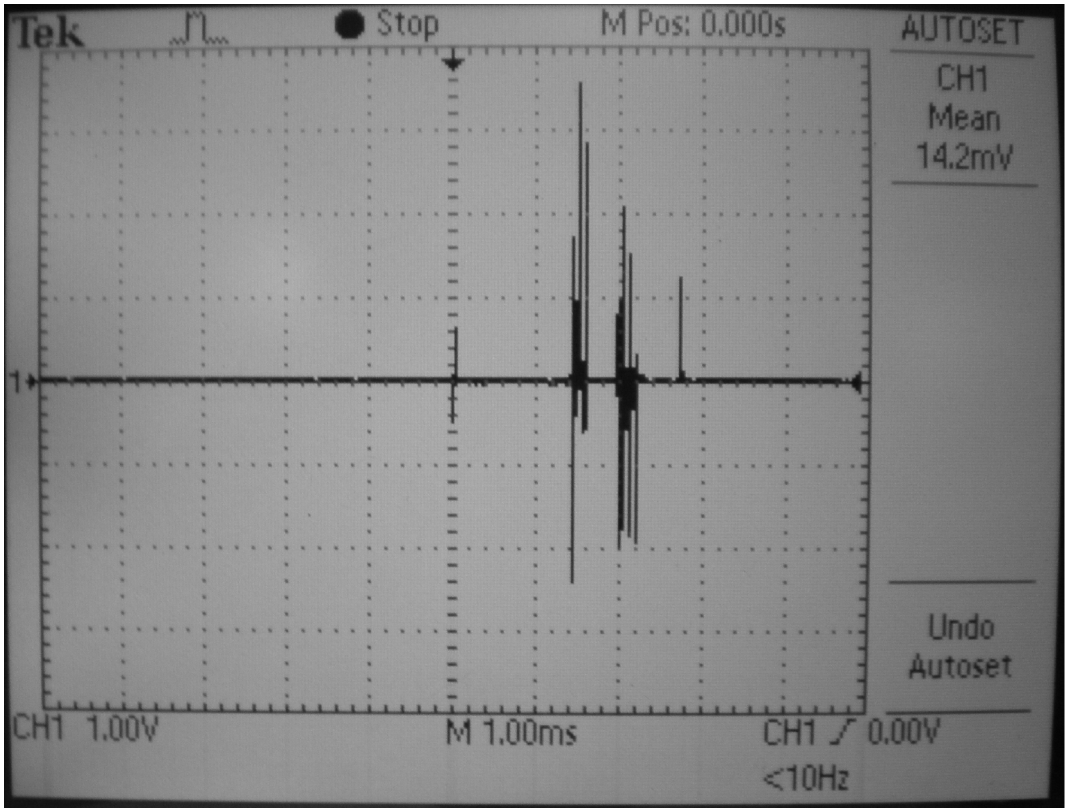


Figure 4.2: Starting waveform without 3V voltage regulation

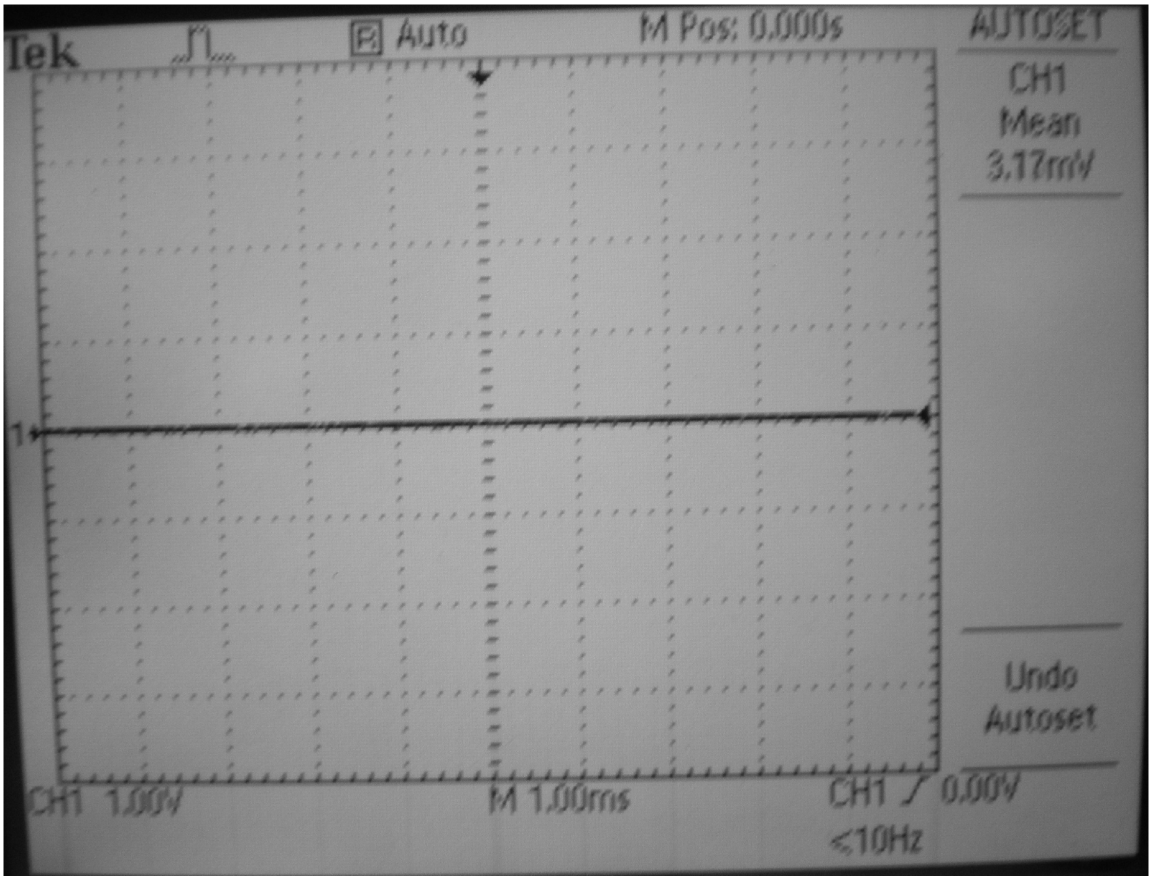


Figure 4.3: Starting waveform with 3V voltage regulator

From the figure 4.1 and 4.2, we can see the different between using 3V regulator, the spike that occur when starting the device can damaging the entire circuits if its not be taken seriously. This result approve that 3V regulator can protect the device in starting stage.

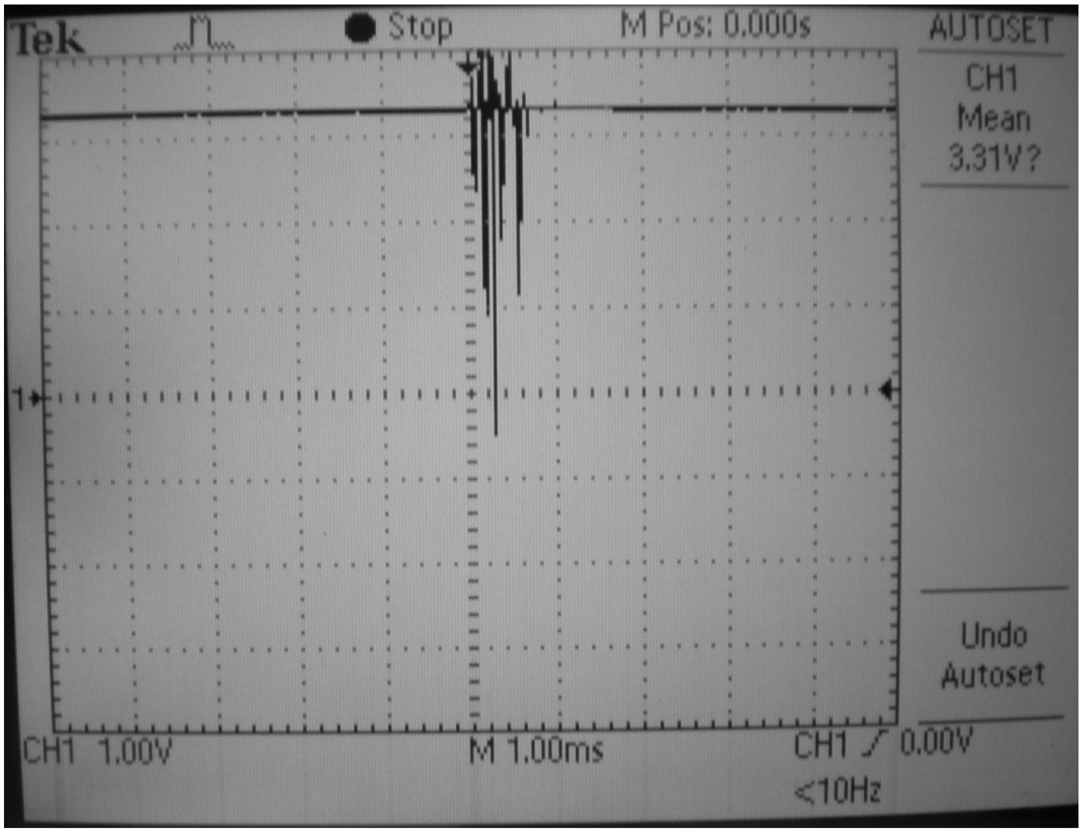


Figure 4.4: Turn off state waveform without 3V voltage regulation

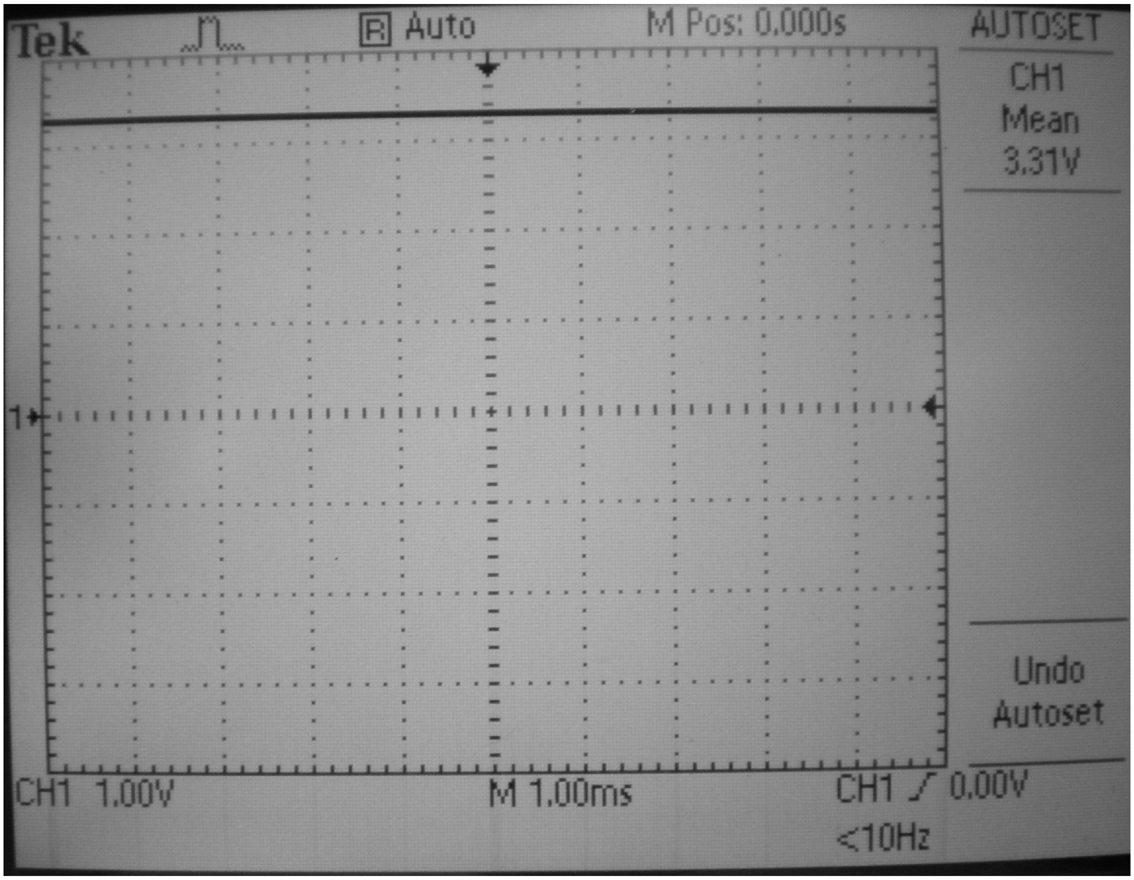


Figure 4.5: Turn off state waveform without 3V voltage regulation

At the stopping the device stage, the same thing happen similar when starting the device, the voltage regulator still do the same process in protecting the entire circuits by eliminating the spikes.

4.3 Final look of the Gadget

The final look of the complete gadget as shown below:

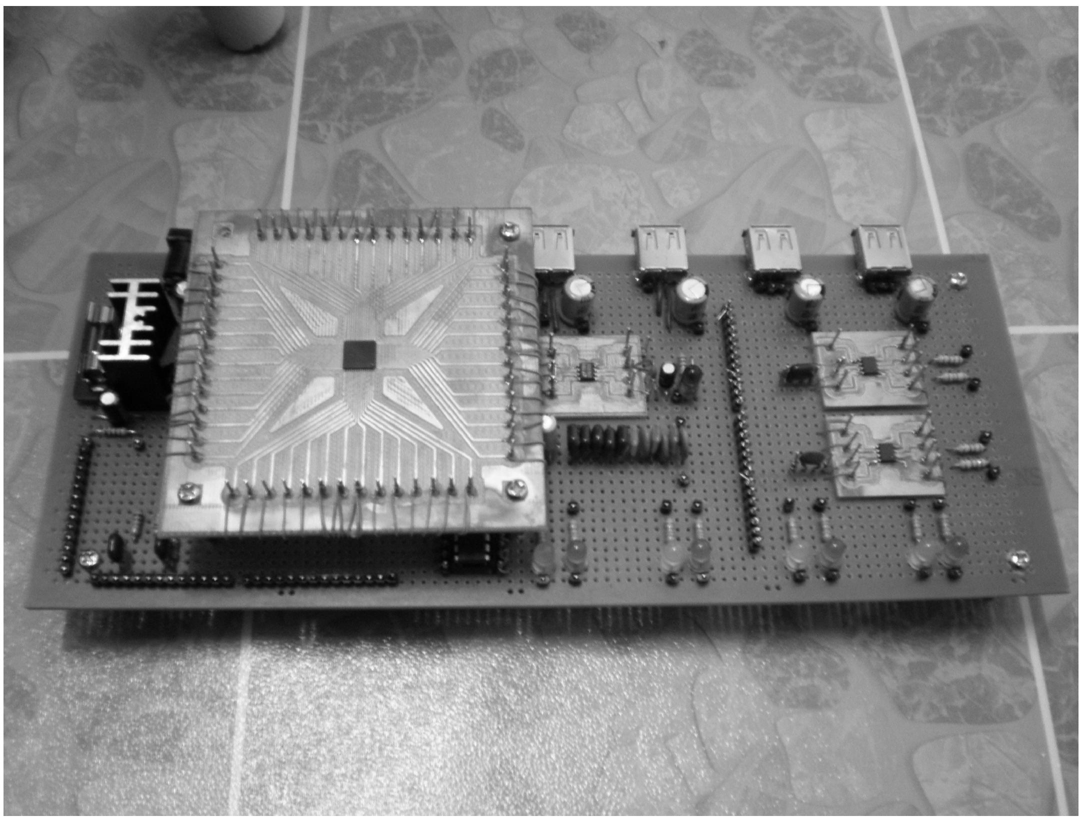


Figure 4.6: USB hub look from back

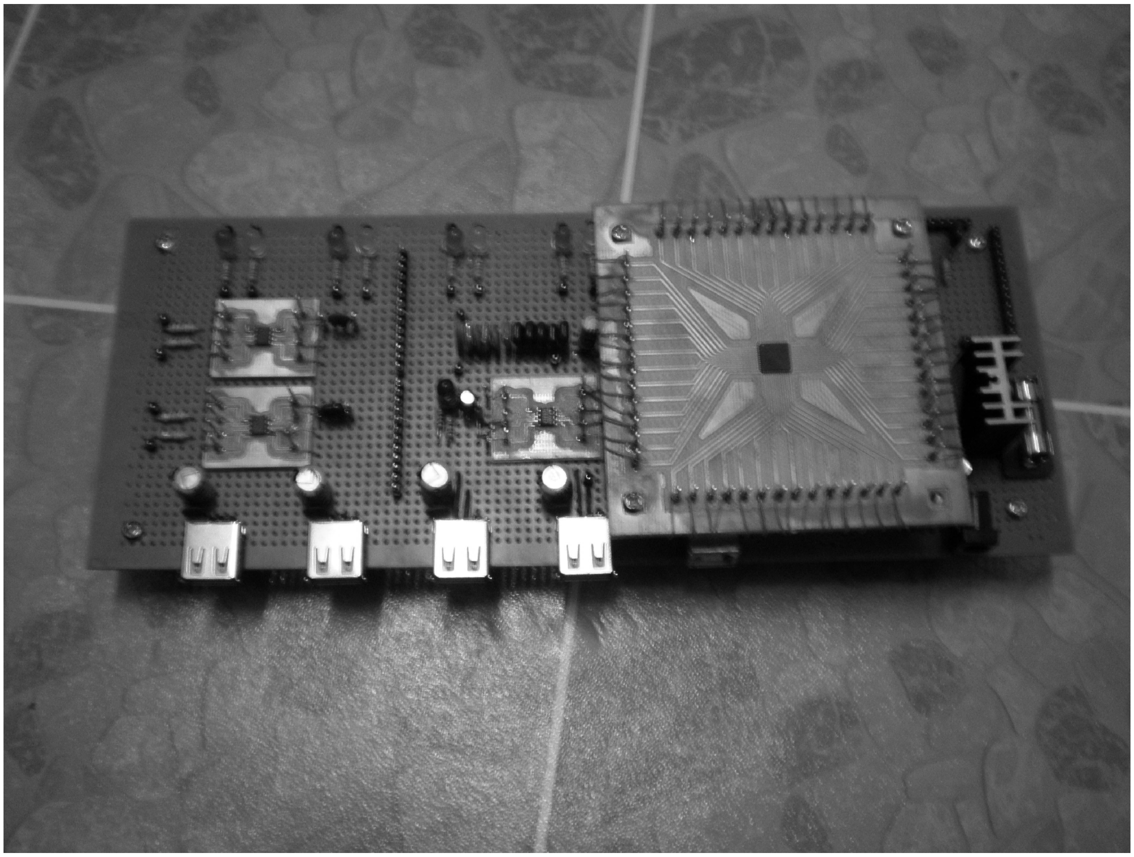


Figure 4.7: USB hub look from front

4.4 Costing and Commercialization

The total cost for this project is only RM 115.10. This project is designed to be very affordable and still function properly. This project has a very high potential for various utilization because communication is very important. If the project is to be commercializing, the project surely will have a good market because it can be used for a long time and had a quality in it.

component	Unit	Price (RM)	Amount (RM)
Capacitor 0.1uF	6	0.30	1.80
Capacitor 150uF 10V	4	0.50	2.00
Capacitor 0.01uF	5	0.30	1.50
Capacitor 22uF 16V	1	0.50	0.50
Capacitor 27pF	2	0.30	0.60
Capacitor 2.2uF 10V	1	0.50	0.50
Capacitor 4.7uF 250V	1	0.50	0.50
Capacitor 10uF 6.3V	1	0.50	0.50
LED red	1	0.20	0.20
LED green	4	0.20	0.80
LED amber	4	0.20	0.80
Power plug	1	2.00	2.00
USB A connector	4	1.00	4.00
USB B connector	1	1.00	1.00
Resistor 15K	8	0.30	2.40
Resistor 1.5K	2	0.30	0.60
Resistor 330K	9	0.30	2.70
Resistor 100K	2	0.30	0.60
Resistor 1M	1	0.30	0.30
USB Controller IC	1	51.42	51.42
3V voltage regulator IC	1	7.00	7.00
Power Management IC	2	9.00	18.00
SPI serial EEPROM	1	7.88	7.88
Socket DIP-8	1	0.30	0.30
Crystal 24MHz	1	3.00	3.00
Board	1	5.00	5.00
TOTAL	**65**		**115.10**

Table 4.1: Overall cost of project

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the project will connect multiple computer devices into hub. After that the data from computer devices will go through USB controller IC and be storage in serial EEPROM temporarily before transmitted into personal computer. Protected circuits needed in this process to make sure any interruption didn’t damaging the entire process. For an example, power management protect downstream port, any over voltage and over current that occur in one port will be terminate without interrupt other port even they had the same power supply. The objectives of this project are successfully achieved. However, there are only certain time that data cannot be transmit due to flaw in IC base design. Lastly, this project is successful and has been very educational and can be used for future reference.

5.2 Difficulties

There are several difficulties that found during the development of this project. Firstly, after the project is done, it is difficult to verify whether the project is functioning properly in transmitting and receiving data. This happen because it is difficult to analyze digital data using electronic devices.

Lastly, there was no device to test whether the USB controller IC is blow out or not. The IC is made up special for USB hub, because of that the IC tester is rarely to be found in the market.

5.3 Suggestions for Future Work.

The USB hub has been used widely as one of computer gadget, constantly day by day, many computer devices will be develop and it must be used USB as their connector due to USB useable capability. This will make us recognize the important of USB hub in the future that need us to upgrade it so that it will have many functions and ability. This project finished in doing research in USB hub and already completed the objective in developing new USB hub with protection circuits, in the future this gadget can be improve by adding other capability such as to be connected onto two devices at one time. Lastly, this project can help inventor in doing their research and also helps student in understanding more details about USB hub.

REFERENCES

[1] Citing sources
URL : http://www.wisegeek.com/what-is-a-usb-hub.htm

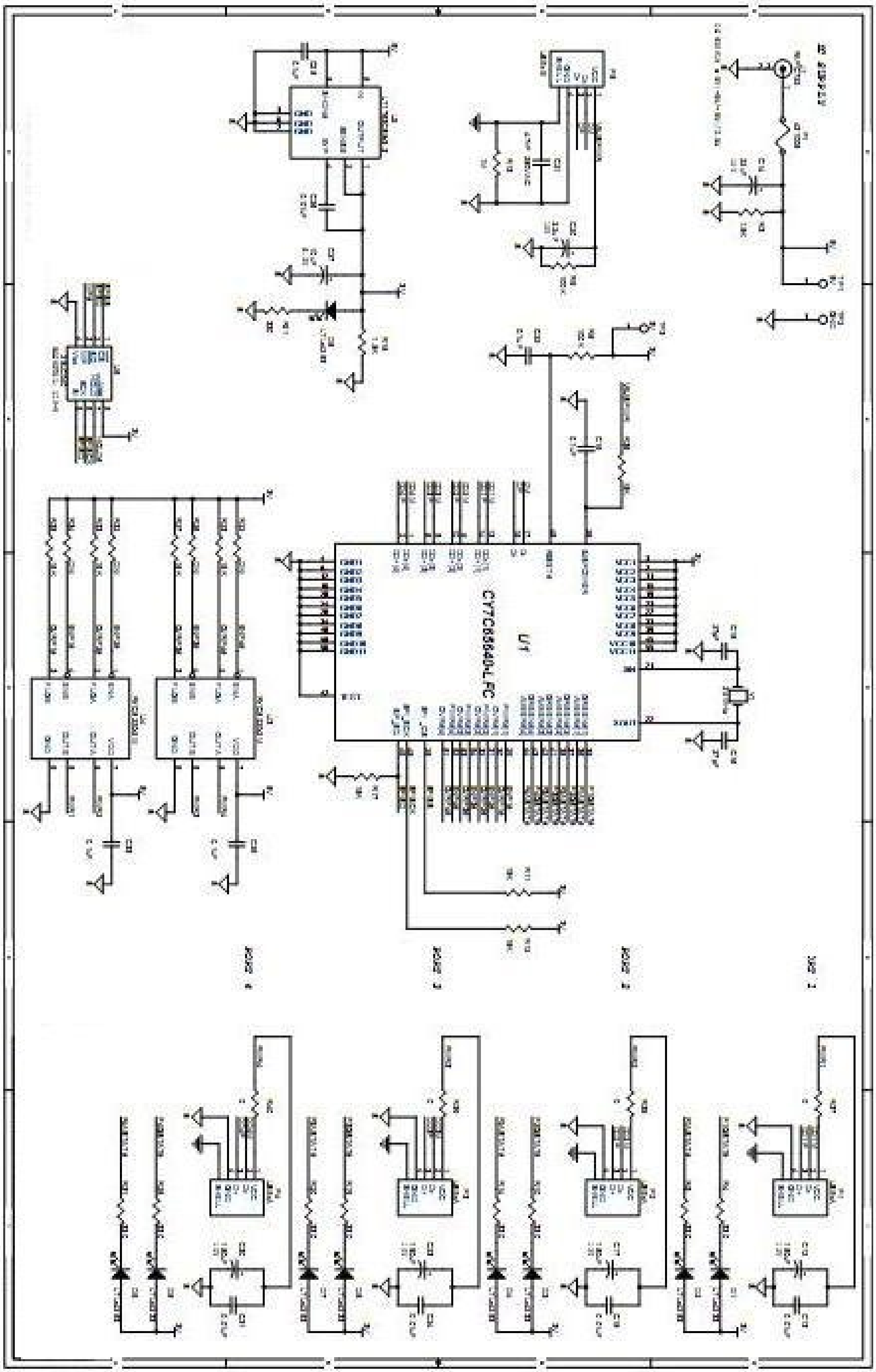
[2] Citing sources
URL : http://computer.howstuffworks.com/usb2.htm

[3] Citing sources
URL : http://en.wikipedia.org/wiki/USB_hub

[4] Citing sources
URL : http://www.microsoft.com/whdc/connect/USB/hubs.mspx

[5] Citing sources
URL : http://www.scienceprog.com/shelling-the-intel-8-bit-hex-file-format/

APPENDIX A
COMPLETE CIRCUIT


U1
CY7C65640-LFC

APPENDIX B

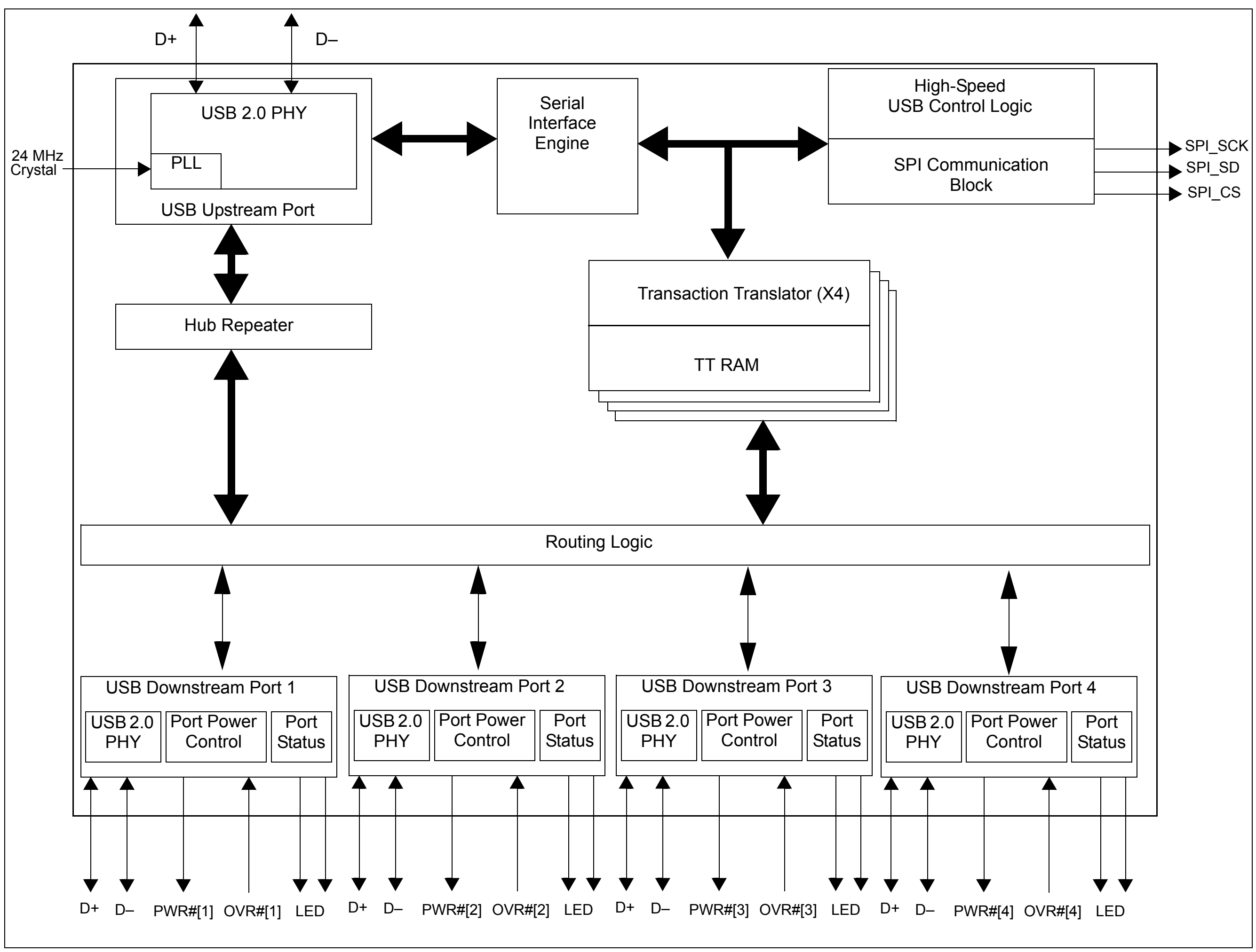
CY7C65640A DATA SHEET

TetraHub™ High-Speed USB Hub Controller

1.0 TetraHub™ Features

- USB 2.0 hub
- Four downstream ports
- Multiple transaction translators—one per downstream port for maximum performance
- VID, PID, and DID configured from external SPI EEPROM
- 24-MHz external crystal
- Small package—Quad Flat Pack, no leads (QFN)
- Integrated upstream pull-up resistor
- Integrated downstream pull-down resistors for all downstream ports
- Integrated upstream and downstream series termination resistors
- Configurable with external SPI EEPROM
  - Number of Active Ports
  - Number of Removable Ports
  - Maximum Power
  - Hub Controller Power
  - Power-On Timer
  - Overcurrent Timer
  - Disable Overcurrent Timer
  - Enable Full-Speed Only
  - Disable Port Indicators
  - Gang Power Switching
  - Enable Single TT Mode Only
  - Enable NoEOPatEOF1

Figure 1-1. Block Diagram



[+] Feedback

2.0 Introduction

Cypress's TetraHub™ is a high-performance self-powered Universal Serial Bus (USB) 2.0 hub. The Tetra architecture provides four downstream USB ports, with a Transaction Translator (TT) for each port, making it the highest-performance hub possible. This single-chip device incorporates one upstream and four downstream USB transceivers, a Serial Interface Engine (SIE), USB Hub Controller and Repeater, and four TTs. It is suitable for standalone hubs, motherboard hubs, and monitor hub applications.

Being a fixed-function USB device, there is no risk or added engineering effort required for firmware development. The developer does not need to write any firmware for their design. The CY4602 Tetrahub USB 2.0 4-port Hub Reference Design Kit provides all materials and documents needed to move rapidly into production. The reference design kit includes board schematics, bill of materials, Gerber files, Orcad files, key application notes, and product description.

CY7C65640A-LFXC is a functional and pin equivalent die revision of Cypress's CY7C65640-LFXC. Changes were made to improve device performance.

2.1 TetraHub Architecture

Figure 1-1 is a block diagram of the TetraHub Architecture.

2.2 USB Serial Interface Engine (SIE)

The SIE allows the CY7C65640A to communicate with the USB host through the USB repeater component of the hub. The SIE handles the following USB bus activity independently of the Hub Control Block:

- Bit stuffing/unstuffing
- Checksum generation/checking
- ACK/NAK/STALL
- TOKEN type identification
- Address checking.

2.3 Hub Controller

The Hub Control Block does the following protocol handling at a higher level:

- Coordinate enumeration by responding to SETUP packets
- Fill and empty the FIFOs
- Suspend/Resume coordination
- Verify and select DATA toggle values
- Port power control and over-current detection.

The Hub Controller provides status and control and permits host access to the hub.

2.4 Hub Repeater

The Hub Repeater manages the connectivity between upstream and downstream facing ports that are operating at the same speed. It supports full-/low-speed connectivity and high-speed connectivity. Per the USB 2.0 specification, the Hub Repeater provides the following functions:

- Sets up and tears down connectivity on packet boundaries
- Ensures orderly entry into and out of the Suspend state, including proper handling of remote wakeups.

2.5 Transaction Translator

The TT basically translates data from one speed to another. A TT takes high-speed split transactions and translates them to full-/low-speed transactions when the hub is operating at high speed (the upstream port is connected to a high-speed host controller) and has full-/low-speed devices attached. The operating speed of a device attached on a downstream facing port determines whether the Routing Logic connects a port to the Transaction Translator or Hub Repeater section. If a low-/full-speed device is connected to the hub operating at high speed, the data transfer route includes the transaction translator. If a high-speed device is connected to this high-speed hub the route only includes the repeater and no transaction translator since the device and the hub are in conformation with respect to their data transfer speed. When the hub is operating at full speed (the upstream port is connected to a full-speed host controller), a high-speed peripheral will not operate at its full capability. These devices will only work at 1.1 speed. Full- and low-speed devices connected to this hub will operate at their 1.1 speed.

3.0 Applications

- Standalone Hubs
- Motherboard Hubs
- Monitor Hub applications
- External Personal Storage Drives
- Port Replicators
- Portable Drive
- Docking Stations

4.0 Functional Overview

The Cypress TetraHub USB 2.0 Hub is a high-performance, low-system-cost solution for USB. The TetraHub USB 2.0 Hub integrates 1.5k upstream pull-up resistors for full-speed operation and all downstream 15k pull-down resistors as well as series termination resistors on all upstream and downstream D+ and D– pins. This results in optimization of system costs by providing built-in support for the USB 2.0 specification.

4.1 System Initialization

On power-up, the TetraHub will read an external SPI EEPROM for configuration information. At the most basic level, this EEPROM will have the Vendor ID (VID), Product ID (PID), and Device ID (DID) for the customer's application. For more specialized applications, other configuration options can be specified. See section 8.0 for more details.

After reading the EEPROM, if BUSPOWER (connected to upstream VBus) is HIGH, TetraHub will enable the pull-up resistor on the D+ to indicate that it is connected to the upstream hub, after which a USB Bus Reset is expected.

During this reset, TetraHub will initiate a chirp to indicate that it is a high-speed peripheral. In a USB 2.0 system, the upstream hub will respond with a chirp sequence, and TetraHub will be in a high-speed mode, with the upstream D+ pull-up resistor turned off. In USB 1.x systems, no such chirp sequence from the upstream hub will be seen, and TetraHub will operate as a normal 1.x hub (operating at full speed).

4.2 Enumeration

After a USB Bus Reset, TetraHub is in an unaddressed, unconfigured state (configuration value set to 0). During the enumeration process, the host will set the hub's address and configuration by sending a SetCongfiguration request. Changing the hub address will restore it to an unconfigured state.

For high-speed multi-TT support, the host must also set the alternate interface setting to 1 (the default mode is single-TT). Once the hub is configured, the full hub functionality is available.

4.3 Multiple Transaction Translator Support

After TetraHub is configured in a high-speed system, it will be in Single TT mode. The host may then set the hub into Multiple TT mode by sending a SetInterface command. In Multiple TT mode, each full-speed port is handled independently and thus has a full 12-Mbps bandwidth available. In Single TT mode, all traffic from the host destined for full- or low-speed ports will be forwarded to all of those ports. This means that the 12-Mbps bandwidth is shared by all full- and low-speed ports.

4.4 Downstream Ports

TetraHub supports a maximum of four downstream ports, each of which may be marked as usable or removable in the extended configuration (0xD2 EEPROM load, see section 8.2). Downstream D+ and D– pull-down resistors are incorporated in TetraHub for each port. Prior to the hub being configured, the ports are driven SE0 (Single Ended Zero, where both D+ and D– are driven LOW) and are set to the unpowered state. Once the hub is configured, the ports are not driven, and the host may power the ports by sending a SetPortPower command to each port. After a port is powered, any connect or disconnect event is detected by the hub. Any change in the port state is reported by the hub back to the host through the Status Change Endpoint (endpoint 1). Upon receipt of SetPortReset command from the host, the hub will

- Drive SE0 on the corresponding port
- Put the port in an enabled state
- Enable the green port indicator for that port (if not previously overridden by the host)
- Enable babble detection once the port is enabled.

Babble consists of either unterminated traffic from a downstream port (or loss of activity), or a non-idle condition on the port after EOF2. If babble is detected on an enabled port, that port will be disabled. A ClearPortEnable command from the host will also disable the specified port.

Downstream ports can be individually suspended by the host with the SetPortSuspend command. If the hub is not suspended, any resume will be confined to that individual port and reflected to the host through a port change indication in the Hub Status Change Endpoint. If the hub is suspended, a resume on this port will be forwarded to the host, but other resume events will not be seen on that port. The host may resume the port by sending a ClearPortSuspend command.

4.5 Upstream Port

The upstream port includes the transmitter and the receiver state machine. The Transmitter and Receiver operate in high-speed and full-speed depending on the current hub configuration.

The transmitter state machine monitors the upstream facing port while the Hub Repeater has connectivity in the upstream direction. This monitoring activity prevents propagation of erroneous indications in the upstream direction. In particular, this machine prevents babble and disconnect events on the downstream facing ports of this hub from propagating and causing the hub to be disabled or disconnected by the hub to which it is attached. This allows the Hub to only disconnect the offensive port on detecting a babble from it.

4.6 Power Switching

TetraHub includes interface signals for external port power switches. Both ganged and individual (per-port) configurations are supported, with individual switching being the default. Initially all ports are unpowered. After enumerating, the host may power each port by sending a SetPortPower command for that port. The power switching and over-current detection of downstream ports is managed by control pins connected to an external power switch device. PWR [n]# output pins of the CY7C65640A series are connected to the respective external power switch's port power enable signals. (Note that each port power output pin of the external power switch must be bypassed with an electrolytic or tantalum capacitor as required by the USB specification. These capacitors supply the inrush currents, which occur during downstream device hot-attach events.)

4.7 Over-current Detection

Over-current detection includes timed detection of 8 ms by default. This parameter is configured from the external EEPROM in a range of 0 ms to 15 ms for both an enabled port and a disabled port individually. Detection of over-current on downstream ports is managed by control pins connected to an external power switch device.

The OVR[n]# pins of the CY7C65640A series are connected to the respective external power switch's port over-current indication (output) signals. Upon detecting an over-current condition, the hub device reports the over-current condition to the host and disables the PWR# output to the external power device.

4.8 Port Indicators

The USB 2.0 port indicators are also supported directly by TetraHub. As per the specification, each downstream port of the hub supports an optional status indicator. The presence of indicators for downstream facing ports is specified by bit 7 of the wHubCharacteristics field of the hub class descriptor. The default TeraHub descriptor specifies that port indicators are supported (wHubCharacteristics, bit 7 is set). If port indicators are not included in the hub, this should be disabled by the EEPROM.

Each port indicator is strategically located directly on the opposite edge of the port which it is associated with. The indicator provides two colors: green and amber. This is implemented as two separate LEDs, one amber and the other green. A combination of hardware and software control is used to inform the user of the current status of the port or the device attached to the port and to guide the user through problem resolution. Colors and blinking are used to provide information to the user. The significance of the color of the LED depends on the operational mode of the TetraHub. There are two modes of operation for the TetraHub port indicators: automatic and manual.

On power-up the TeraHub defaults to Automatic Mode, where the color of the Port Indicator (Green, Amber, Off) indicates the functional status of the TetraHub port. In Automatic Mode, TetraHub will turn on the green LED whenever the port is enabled and the amber LED when it has had an over-current condition detected. The color of the port indicator is set by the port state machine. Blinking of the LEDs is not supported in Automatic Mode. *Table 4-1* below identifies the mapping of color to port state in Automatic Mode.

In manual mode, the indicators are under the control of the host, which can turn on one of the LEDs, or leave them off. This is done by a system software USB Hub class request. Blinking of the LEDs is supported in Manual Mode. The port indicators allow the user to intervene on any error detection. For example, when babble is detected on plugging in a defective device, or on occurrence of an overcurrent condition, the port indicators corresponding to the downstream port will blink green or only light the amber LED, respectively. *Table 4-2* below displays the color definition of the indicators when TetraHub is in Manual Mode.

Table 4-1. Automatic Port State to Port Indicator Color Mapping

Port Switching	Downstream Facing Hub Port State			
	Powered Off	**Disconnected, Disabled, Not Configured, Resetting, Testing**	**Enabled, Transmit, or TransmitR**	**Suspended, Resuming, SendEOR, Restart_E/S**
With	Off or Amber if due to an Overcurrent Condition	Off	Green	Off
Without	Off	Off or Amber if due to an Overcurrent Condition	Green	Off

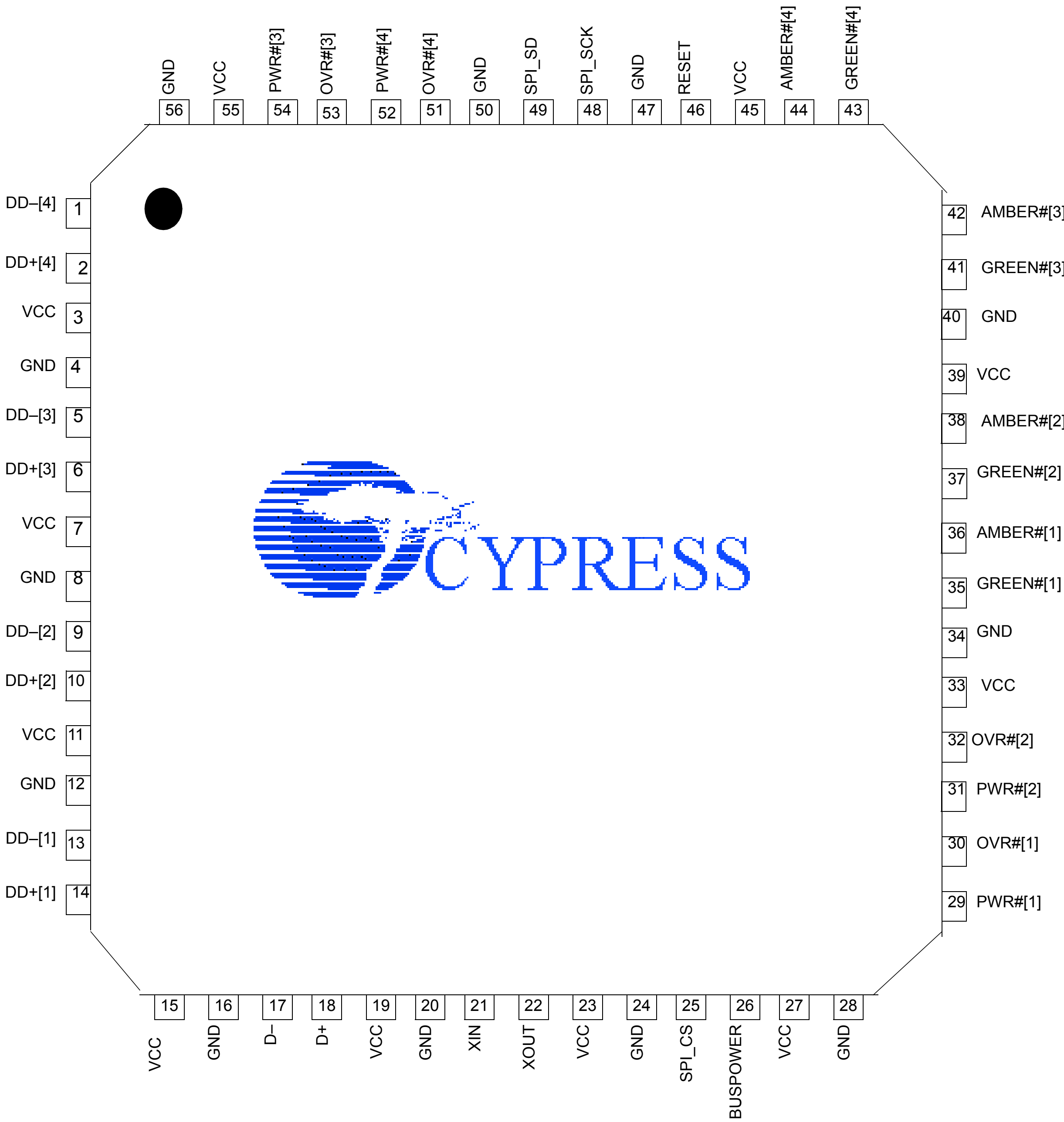
Table 4-2. Port Indicator Color Definitions in Manual Mode

Color Definition	Port State
Off	Not operational
Amber	Error condition
Green	Fully Operational
Blinking Off/Green	Software Attention
Blinking Off/Amber	Hardware Attention
Blinking Green/Amber	Reserved

Note. Information presented in *Table 4-1* and *Table 4-2* is from USB 2.0 specification Tables 11-6 and 11-7, respectively.

5.0 Pin Configuration

Figure 5-1. 56-pin Quad Flat Pack No Leads (8 mm x 8 mm)



6.0 Pin Description Table

Table 6-1 below displays the pin assignments for the CY7C65640A.

Table 6-1. Pin Assignments

Pin	Name	Type	Default	Description
3	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
7	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
11	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
15	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
19	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
23	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
27	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
33	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
39	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
45	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
55	VCC	Power	N/A	**V_{CC}**. This signal provides power to the chip.
4	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
8	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
12	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
16	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
20	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
24	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
28	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
34	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
40	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
47	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
50	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
56	GND	Power	N/A	**GND**. Connect to Ground with as short a path as possible.
21	XIN	Input	N/A	**24-MHz Crystal IN or External Clock Input**.
22	XOUT	Output	N/A	**24-MHz Crystal OUT**.
46	RESET#	Input	N/A	**Active LOW Reset**. This pin resets the entire chip. It is normally tied to V_{CC} through a 100K resistor, and to GND through a 0.1-μF capacitor. Other than this, no other special power-up procedure is required.
26	BUSPOWER	Input	N/A	**VBUS**. Connect to the VBUS pin of the upstream connector. This signal indicates to the hub that it is in a powered state, and may enable the D+ pull-up resistor to indicate a connection. (The hub will do so after the external EEPROM is read, unless it is put into a high-speed mode by the upstream hub). The hub can not be bus powered, and the VBUS signal must not be used as a power source.
SPI INTERFACE				
25	SPI_CS	O	O	**SPI Chip Select**. Connect to CS pin of the EEPROM.
48	SPI_SCK	O	O	**SPI Clock**. Connect to EEPROM SCK pin.
49	SPI_SD	I/O/Z	Z	**SPI Dataline Connect to GND** with 15-KΩ resistor and to the Data I/O pins of the EEPROM.
UPSTREAM PORT				
17	D–	I/O/Z	Z	**Upstream D– Signal**.
18	D+	I/O/Z	Z	**Upstream D+ Signal**.

Table 6-1. Pin Assignments (continued)

Pin	Name	Type	Default	Description
DOWNSTREAM PORT 1				
13	DD–[1]	I/O/Z	Z	**Downstream D– Signal**.
14	DD+[1]	I/O/Z	Z	**Downstream D+ Signal**.
36	AMBER#[1]	O	1	**LED**. Driver output for Amber LED. Port Indicator Support. Active LOW.
35	GREEN#[1]	O	1	**LED**. Driver output for Green LED. Port Indicator Support. Active LOW.
30	OVR#[1]	Input	1	**Overcurrent Condition Detection Input**. Active LOW.
29	PWR#[1]	O/Z	Z	**Power Switch Driver Output**. Active LOW.
DOWNSTREAM PORT 2				
9	DD–[2]	I/O/Z	Z	**Downstream D– Signal**.
10	DD+[2]	I/O/Z	Z	**Downstream D+ Signal**.
38	AMBER#[2]	O	1	**LED**. Driver output for Amber LED. Port Indicator Support. Active LOW.
37	GREEN#[2]	O	1	**LED**. Driver output for Green LED. Port Indicator Support. Active LOW.
32	OVR#[2]	Input	1	**Overcurrent Condition Detection Input**. Active LOW.
31	PWR#[2]	O/Z	Z	**Power Switch Driver Output**. Active LOW.
DOWNSTREAM PORT 3				
5	DD–[3]	I/O/Z	Z	**Downstream D– Signal**.
6	DD+[3]	I/O/Z	Z	**Downstream D+ Signal**.
42	AMBER#[3]	O	1	**LED**. Driver output for Amber LED. Port Indicator Support. Active LOW.
41	GREEN#[3]	O	1	**LED**. Driver output for Green LED. Port Indicator Support. Active LOW.
53	OVR#[3]	Input	1	**Overcurrent Condition Detection Input**. Active LOW.
54	PWR#[3]	O/Z	Z	**Power Switch Driver Output**. Active LOW.
DOWNSTREAM PORT 4				
1	DD–[4]	I/O/Z	Z	**Downstream D– Signal**.
2	DD+[4]	I/O/Z	Z	**Downstream D+ Signal**.
44	AMBER#[4]	O	1	**LED**. Driver output for Amber LED. Port Indicator Support. Active LOW.
43	GREEN#[4]	O	1	**LED**. Driver output for Green LED. Port Indicator Support. Active LOW.
51	OVR#[4]	Input	1	**Overcurrent Condition Detection Input**. Active LOW.
52	PWR#[4]	O/Z	Z	**Power Switch Driver Output**. Active LOW.

Unused port DD+/DD– lines can be left floating. The port power, amber, and green LED pins should be left unconnected, and the overcurrent pin should be tied HIGH. The overcurrent pin is an input and it should not be left floating.

7.0 Default Descriptors

7.1 Device Descriptor

The standard device descriptor for TetraHub is based on the VID, PID, and DID found in the SPI EEPROM. This VID/PID/DID in the EEPROM will overwrite the default VID/PID/DID. If no EEPROM is used, the TetraHub will enumerate with the default descriptor values as shown below.

Byte	Full Speed	High Speed	Field Name	Description
0	0x12	0x12	bLength	18 Bytes
1	0x01	0x01	bDescriptorType	DEVICE_DESCRIPTOR
2,3	0x0200	0x0200	bcdUSB	USB specification 2.0
4	0x09	0x09	bDeviceClass	HUB
5	0x00	0x00	bDeviceSubClass	None

Byte	Full Speed	High Speed	Field Name	Description
6	0x00	0x02	bDeviceProtocol	None
7	0x40	0x40	bMaxPacketSize0	64 bytes
8,9	0x04B4	0xx04B4	wIdVendor	VID (overwritten by what is defined in EEPROM)
10,11	0x6560	0x6560	wIdProduct	PID (overwritten by what is defined in EEPROM)
12, 13	0x000B	0x000B	wbcdDevice	DID (overwritten by what is defined in EEPROM)
14	0x00	0x00	iManufacturer	No manufacturer string supported
15	0x00	0x00	iProduct	No product string supported
16	0x00	0x00	iSerialNumber	No serial string supported
17	0x01	0x01	bNumConfigurations	One configuration supported

7.2 Configuration Descriptor

Byte	Full Speed	High Speed	Field Name	Description
0	0x09	0x09	bLength	9 Bytes
1	0x02	0x02	bDescriptorType	CONFIG_DESCRIPTOR
2	0x0019	0x0029[1]	wTotalLength	Length of all other descriptors
4	0x01	0x01	bNumInterfaces	1
5	0x01	0x01	bConfigurationValue	The configuration to be used
6	0x00	0x00	iConfiguration	
7	0xE0	0xE0	bmAttributes	
8	0x32	0x32[2]	bMaxPower	

7.3 Interface Descriptor

Byte	Full Speed	High Speed	Field Name	Description
0	0x09	0x09	bLength	9 Bytes
1	0x04	0x04	bDescriptorType	INTERFACE_DESCRIPTOR
2	0x00	0x00	bInterfaceNumber	
3	0x00	0x00	bAlternateSetting	
4	0x01	0x01	bNumEndpoints	
5	0x09	0x09	bInterfaceClass	
6	0x00	0x00	bInterfaceSubClass	
7	0x00	0x01	bInterfaceProtocol	
8	0x00	0x00	iInterface	

Notes

1. This value is reported as 0x19 if the hub is configured in Single-TT mode.
2. This value is configured through the External EEPROM.

7.4 Endpoint Descriptor

Byte	Full Speed	High Speed	Field Name	Description
0	0x07	0x07	bLength	7 Bytes
1	0x05	0x05	bDescriptorType	ENDPOINT_DESCRIPTOR
2	0x81	0x81	bEndpointAddress	IN Endpoint #1
3	0x03	0x03	bmAttributes	Interrupt
4,5	0x0001	0x0001	wMaxPacketSize	Maximum Packet Size
6	0xFF	0x0C	bInterval	Polling Rate

7.5 Interface Descriptor[3]

Byte	Full Speed	High Speed	Field Name	Description
0	N/A	0x09	bLength	9 Bytes
1	N/A	0x04	bDescriptorType	INTERFACE_DESCRIPTOR
2	N/A	0x00	bInterfaceNumber	Interface Descriptor Index
3	N/A	0x01	bAlternateSetting	Alternate Setting for the Interface
4	N/A	0x01	bNumEndpoints	Number of Endpoints Defined
5	N/A	0x09	bInterfaceClass	Interface Class
6	N/A	0x00	bInterfaceSubClass	Interface Sub-Class
7	N/A	0x02	bInterfaceProtocol	Interface Protocol
8	N/A	0x00	bInterface	Interface String Index

7.6 Endpoint Descriptor[3]

Byte	Full Speed	High Speed	Field Name	Description
0	N/A	0x07	bLength	7 Bytes
1	N/A	0x05	bDescriptorType	ENDPOINT_DESCRIPTOR
2	N/A	0x81	bEndpointAddress	IN Endpoint #1
3	N/A	0x03	bmAttributes	Interrupt
4,5	N/A	0x0001	wMaxPacketSize	Maximum Packet Size
6	N/A	0x0C	bInterval	Polling Rate

Note

3. If TetraHub is configured for single-TT only (from the external EEPROM), this descriptor is not present.

7.7 Device Qualifier Descriptor

Byte	Full Speed	High Speed	Field Name	Description
0	0x0A	0x0A	bLength	10 Bytes
1	0x06	0x06	bDescriptorType	DEVICE_QUALIFIER
2,3	0x0200	0x0200	bcdUSB	
4	0x09	0x09	bDeviceClass	
5	0x00	0x00	bDeviceSubClass	
6	0x02	0x00	bDeviceProtocol	
7	0x40	0x40	bMaxPacketSize0	
8	0x01	0x01	bNumConfigurations	
9	0x00	0x00	bReserved	

7.8 Hub Descriptor

Byte	All Speeds	Field Name	Description
0	0x09	bLength	9 Bytes
1	0x29	bDescriptorType	HUB Descriptor
2	0x04[7.8]	bNbrPorts	Number of ports supported
3,4	0x0089[7.8]	wHubCharacteristics	b1, b0: Logical Power Switching Mode 00: Ganged power switching (all ports' power at once) 01: Individual port power switching (Default in TetraHub) b2: Identifies a Compound Device, 0: Hub is not part of a compound device (Default in TetraHub), 1: Hub is part of a compound device. b4, b3: Over-current Protection Mode 00: Global Overcurrent Protection. The hub reports overcurrent as a summation of all ports current draw, without a breakdown of individual port overcurrent status. 01: Individual Port Overcurrent Protection. The hub reports overcurrent on a per-port basis. Each port has an over-current status (Default in TetraHub). 1X: No Overcurrent Protection. This option is allowed only for bus-powered hubs that do not implement overcurrent protection. b6, b5: TT Think Time 00: TT requires at most 8 FS bit times of inter transaction gap on a full-/low-speed downstream bus (Default in TetraHub). 01: TT requires at most 16 FS bit times. 10: TT requires at most 24 FS bit times. 11: TT requires at most 32 FS bit times. b7: Port Indicators Supported, 0: Port Indicators are not supported on its downstream facing ports and the PORT_INDICATOR request has no effect. 1: Port Indicators are supported on its downstream facing ports and the PORT_INDICATOR request controls the indicators. See Section 4 and 9 (Default in TetraHub). b15...b8: Reserved
5	0x32[7.8]	bPwrOn2PwrGood	Time from when the port is powered to when the power is good on that port
6	0x64[7.8]	bHubContrCurrent	Maximum current requirement for the Hub Controller
7	0x00[7.8]	bDeviceRemovable	Indicates if the port has a removable device attached
8	0xFF[7.8]	bPortPwrCtrlMask	Required for compatibility with software written for 1.0 compliant devices

Note

4. This value is configured through the External EEPROM.

14.0 Electrical Characteristics

14.1 Absolute Maximum Ratings

Storage Temperature ....–65°C to +150 °C

Ambient Temperature with Power Applied ....0°C to +70°C

Supply Voltage to Ground Potential .... –0.5V to +4.0V

DC Voltage Applied to Outputs in High Z State ....–0.5V to V_{CC} + 0.5V

Power Dissipation (4 HS ports)......................................1.6W

Static Discharge Voltage.. > 2000V

Max. Output Sink Current per I/O .... 10 mA

14.2 Operating Conditions

T_A (Ambient Temperature Under Bias)............. 0°C to +70°C

Supply Voltage...+3.15V to +3.45V

Ground Voltage... 0V

FOSC (Oscillator or Crystal Frequency).....24 MHz ± 0.05%, parallel resonant, fundamental mode

14.3 DC Electrical Characteristics

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
V_{CC}	Supply Voltage		3.15	3.3	3.45	V
V_{IH}	Input High Voltage		2		5.25	V
V_{IL}	Input Low Voltage		–0.5		0.8	V
I_I	Input Leakage Current	$0 < V_{IN} < V_{CC}$			±10	µA
V_{OH}	Output Voltage High	I_{OUT} = 4 mA	2.4			V
V_{OL}	Output Low Voltage	I_{OUT} = –4 mA			0.4	V
I_{OH}	Output Current High				4	mA
I_{OL}	Output Current Low				4	mA
C_{IN}	Input Pin Capacitance				10	pF
I_{SUSP}	Suspend Current			100		µA
I_{CC}	**Supply Current**					
	4 Active ports	Full-speed Host, Full-speed Devices		255		mA
		High-speed Host, High-speed Devices		460		mA
		High-speed Host, Full-speed Devices		395		mA
	2 Active Ports	Full-speed Host, Full-speed Devices		255		mA
		High-speed Host, High-speed Devices		415		mA
		High-speed Host, Full-speed Devices		380		mA
	No Active Ports	Full-speed Host		255		mA
		High-speed Host		370		mA
USB Transceiver						
Z_{HSDRV}	Driver Output Resistance		41	45	49	Ω
I_i	Input Leakage Current			±0.1	±5	µA
I_{OZ}	Three-state Output OFF-State Current				±10	µA
V_{HSRS}	High-speed Receiver Sensitivity Level		210			mV
T_{rfi}	Full-speed Frame Jitter				133	ns
Thermal Resistance						
T_{JA}	Theta Thermal Coefficient Junction to Ambient	E-Pad configuration in section 16.1 at zero airflow	23.27			°C/W

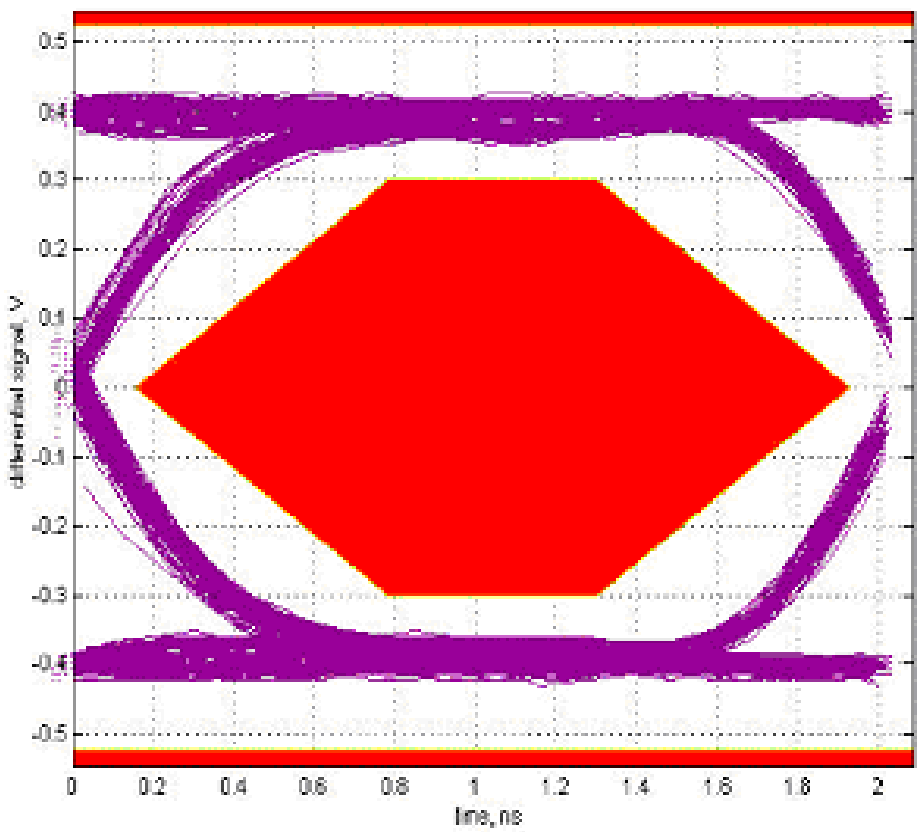
14.4 AC Electrical Characteristics

Both the upstream USB transceiver and all four downstream transceivers have passed the USB-IF USB 2.0 Electrical Certification Testing.

14.4.1 Serial Peripheral Interface

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
	Clock Rise/Fall Time				500	ns
	Clock Frequency				250	kHz
	Data Set-up Time		50			ns
	Hold Time		100			ns
	Reset period		1.9			ms

14.4.2 Eye Diagram



15.0 Ordering Information

Ordering Code	Package Type
CY7C65640A-LFXC	56-pin QFN Lead-free Package
CY4602	TetraHub USB 2.0 4 port Hub Reference Design Kit

APPENDIX C
LT1763-3.3 DATA SHEET

500mA, Low Noise, LDO Micropower Regulators

FEATURES

- **Low Noise: 20µV$_{RMS}$ (10Hz to 100kHz)**
- **Output Current: 500mA**
- **Low Quiescent Current: 30µA**
- **Wide Input Voltage Range: 1.8V to 20V**
- **Low Dropout Voltage: 300mV**
- **Very Low Shutdown Current: < 1µA**
- No Protection Diodes Needed
- Fixed Output Voltages: 1.5V, 1.8V, 2.5V, 3V, 3.3V, 5V
- Adjustable Output from 1.22V to 20V
- Stable with 3.3µF Output Capacitor
- Stable with Aluminum, Tantalum or Ceramic Capacitors
- Reverse Battery Protection
- No Reverse Current
- Overcurrent and Overtemperature Protected
- 8-Lead SO and 12-lead (4mm × 3mm) DFN Packages

APPLICATIONS

- Cellular Phones
- Battery-Powered Systems
- Noise-Sensitive Instrumentation Systems

DESCRIPTION

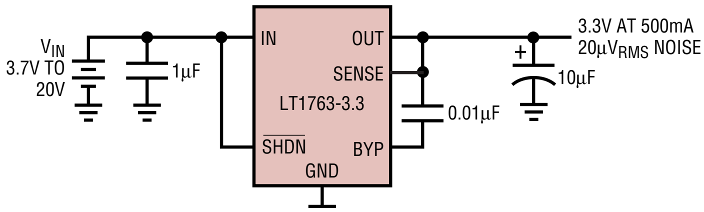
The LT®1763 series are micropower, low noise, low dropout regulators. The devices are capable of supplying 500mA of output current with a dropout voltage of 300mV. Designed for use in battery-powered systems, the low 30µA quiescent current makes them an ideal choice. Quiescent current is well controlled; it does not rise in dropout as it does with many other regulators.

A key feature of the LT1763 regulators is low output noise. With the addition of an external 0.01µF bypass capacitor, output noise drops to 20µV$_{RMS}$ over a 10Hz to 100kHz bandwidth. The LT1763 regulators are stable with output capacitors as low as 3.3µF. Small ceramic capacitors can be used without the series resistance required by other regulators.

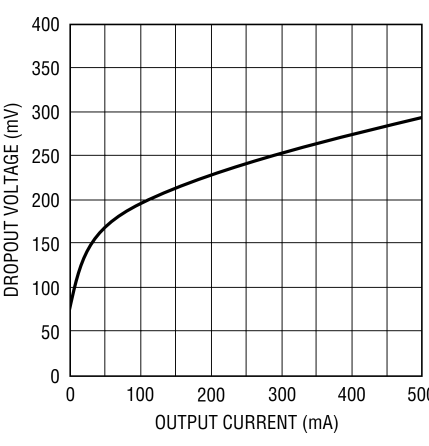
Internal protection circuitry includes reverse battery protection, current limiting, thermal limiting and reverse current protection. The parts come in fixed output voltages of 1.5V, 1.8V, 2.5V, 3V, 3.3V and 5V, and as an adjustable device with a 1.22V reference voltage. The LT1763 regulators are available in 8-lead SO and 12-lead, low profile (4mm × 3mm × 0.75mm) DFN packages.

TYPICAL APPLICATION

3.3V Low Noise Regulator



Dropout Voltage



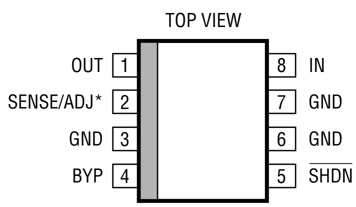
ABSOLUTE MAXIMUM RATINGS

(Note 1)

IN Pin Voltage .... ±20V
OUT Pin Voltage .... ±20V
Input to Output Differential Voltage .... ±20V
SENSE Pin Voltage .... ±20V
ADJ Pin Voltage .... ±7V
BYP Pin Voltage .... ±0.6V
SHDN Pin Voltage .... ±20V
Output Short-Circuit Duration .... Indefinite

Operating Junction Temperature Range (Note 2)
C Grade .... –40°C to 125°C
MP Grade .... –55°C to 125°C
Storage Temperature Range
S8 Package .... –65°C to 150°C
DFN Package .... –65°C to 125°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION

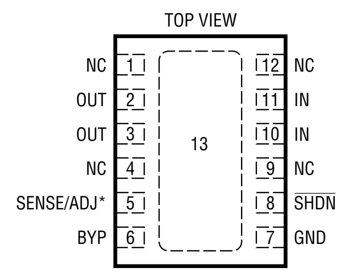


S8 PACKAGE
8-LEAD PLASTIC SO

*PIN 2: SENSE FOR LT1763-1.5/
LT1763-1.8/LT1763-2.5/
LT1763-3/LT1763-3.3/LT1763-5
ADJ FOR LT1763

$T_{JMAX} = 150°C$, $\theta_{JA} = 70°C/W$,
$\theta_{JC} = 35°C/W$

SEE THE APPLICATIONS INFORMATION SECTION.



DE12 PACKAGE
12-LEAD (4mm × 3mm) PLASTIC DFN
EXPOSED PAD (PIN 13) IS GND. MUST BE
SOLDERED TO THE PCB.

*PIN 5: SENSE FOR LT1763-1.5/
LT1763-1.8/LT1763-2.5/
LT1763-3/LT1763-3.3/LT1763-5
ADJ FOR LT1763

$T_{JMAX} = 125°C$, $\theta_{JA} = 40°C/W$,
$\theta_{JC} = 5°C/W$

SEE THE APPLICATIONS INFORMATION SECTION.

ORDER PART NUMBER	S8 PART MARKING	ORDER PART NUMBER	DE PART MARKING
LT1763CS8	1763	LT1763CDE	1763
LT1763CS8-1.5	176315	LT1763CDE-1.5	76315
LT1763CS8-1.8	176318	LT1763CDE-1.8	76318
LT1763CS8-2.5	176325	LT1763CDE-2.5	76325
LT1763CS8-3	17633	LT1763CDE-3	17633
LT1763CS8-3.3	176333	LT1763CDE-3.3	76333
LT1763CS8-5	17635	LT1763CDE-5	17635
LT1763MPS8	1763MP		

Order Options Tape and Reel: Add #TR
Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF
Lead Free Part Marking: http://www.linear.com/leadfree/

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are $T_A = 25°C$. (Note 2)

PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Minimum Operating Voltage	C Grade: I_{LOAD} = 500mA (Notes 3, 11)		●		1.8	2.3	V
	MP Grade: I_{LOAD} = 500mA (Notes 3, 11)		●		1.8	2.35	V
Regulated Output Voltage (Note 4)	LT1763-1.5	V_{IN} = 2V, I_{LOAD} = 1mA		1.485	1.5	1.515	V
		2.5V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	1.462	1.5	1.538	V
	LT1763-1.8	V_{IN} = 2.3V, I_{LOAD} = 1mA		1.782	1.8	1.818	V
		2.8V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	1.755	1.8	1.845	V
	LT1763-2.5	V_{IN} = 3V, I_{LOAD} = 1mA		2.475	2.5	2.525	V
		3.5V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	2.435	2.5	2.565	V
	LT1763-3	V_{IN} = 3.5V, I_{LOAD} = 1mA		2.970	3	3.030	V
		4V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	2.925	3	3.075	V
	LT1763-3.3	V_{IN} = 3.8V, I_{LOAD} = 1mA		3.267	3.3	3.333	V
		4.3V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	3.220	3.3	3.380	V
	LT1763-5	V_{IN} = 5.5V, I_{LOAD} = 1mA		4.950	5	5.050	V
		6V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	4.875	5	5.125	V
ADJ Pin Voltage (Notes 3, 4)	LT1763	V_{IN} = 2.2V, I_{LOAD} = 1mA		1.208	1.220	1.232	V
		C Grade: 2.3V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	1.190	1.220	1.250	V
		MP Grade: 2.35V < V_{IN} < 20V, 1mA < I_{LOAD} < 500mA	●	1.190	1.220	1.250	V
Line Regulation	LT1763-1.5	ΔV_{IN} = 2V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763-1.8	ΔV_{IN} = 2.3V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763-2.5	ΔV_{IN} = 3V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763-3	ΔV_{IN} = 3.5V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763-3.3	ΔV_{IN} = 3.8V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763-5	ΔV_{IN} = 5.5V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763 (Note 3)	C Grade: ΔV_{IN} = 2V to 20V, I_{LOAD} = 1mA	●		1	5	mV
	LT1763 (Note 3)	MP Grade: ΔV_{IN} = 2.1V to 20V, I_{LOAD} = 1mA	●		1	5	mV
Load Regulation	LT1763-1.5	V_{IN} = 2.5V, ΔI_{LOAD} = 1mA to 500mA			3	8	mV
		V_{IN} = 2.5V, ΔI_{LOAD} = 1mA to 500mA	●			15	mV
	LT1763-1.8	V_{IN} = 2.8V, ΔI_{LOAD} = 1mA to 500mA			4	9	mV
		V_{IN} = 2.8V, ΔI_{LOAD} = 1mA to 500mA	●			18	mV
	LT1763-2.5	V_{IN} = 3.5V, ΔI_{LOAD} = 1mA to 500mA			5	12	mV
		V_{IN} = 3.5V, ΔI_{LOAD} = 1mA to 500mA	●			25	mV
	LT1763-3	V_{IN} = 4V, ΔI_{LOAD} = 1mA to 500mA			7	15	mV
		V_{IN} = 4V, ΔI_{LOAD} = 1mA to 500mA	●			30	mV
	LT1763-3.3	V_{IN} = 4.3V, ΔI_{LOAD} = 1mA to 500mA			7	17	mV
		V_{IN} = 4.3V, ΔI_{LOAD} = 1mA to 500mA	●			33	mV
	LT1763-5	V_{IN} = 6V, ΔI_{LOAD} = 1mA to 500mA			12	25	mV
		V_{IN} = 6V, ΔI_{LOAD} = 1mA to 500mA	●			50	mV
	LT1763 (Note 3)	V_{IN} = 2.3V, ΔI_{LOAD} = 1mA to 500mA			2	6	mV
		C Grade: V_{IN} = 2.3V, ΔI_{LOAD} = 1mA to 500mA	●			12	mV
		MP Grade: V_{IN} = 2.35V, ΔI_{LOAD} = 1mA to 500mA	●			12	mV
Dropout Voltage $V_{IN} = V_{OUT(NOMINAL)}$ (Notes 5, 6, 11)	I_{LOAD} = 10mA				0.13	0.19	V
	I_{LOAD} = 10mA		●			0.25	V
	I_{LOAD} = 50mA				0.17	0.22	V
	I_{LOAD} = 50mA		●			0.32	V
	I_{LOAD} = 100mA				0.20	0.24	V
	I_{LOAD} = 100mA		●			0.34	V
	I_{LOAD} = 500mA				0.30	0.35	V
	I_{LOAD} = 500mA		●			0.45	V

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are T_A = 25°C. (Note 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
GND Pin Current $V_{IN} = V_{OUT(NOMINAL)}$ (Notes 5, 7)	I_{LOAD} = 0mA I_{LOAD} = 1mA I_{LOAD} = 50mA I_{LOAD} = 100mA I_{LOAD} = 250mA I_{LOAD} = 500mA	● ● ● ● ● ●		30 65 1.1 2 5 11	75 120 1.6 3 8 16	μA μA mA mA mA mA
Output Voltage Noise	C_{OUT} = 10μF, C_{BYP} = 0.01μF, I_{LOAD} = 500mA, BW = 10Hz to 100kHz			20		μV_{RMS}
ADJ Pin Bias Current	(Notes 3, 8)			30	100	nA
Shutdown Threshold	V_{OUT} = Off to On V_{OUT} = On to Off	● ●	 0.25	0.8 0.65	2	V V
$\overline{SHDN}$ Pin Current (Note 9)	$V_{\overline{SHDN}}$ = 0V $V_{\overline{SHDN}}$ = 20V			0.1 1		μA μA
Quiescent Current in Shutdown	V_{IN} = 6V, $V_{\overline{SHDN}}$ = 0V			0.1	1	μA
Ripple Rejection	$V_{IN} - V_{OUT}$ = 1.5V (Avg), V_{RIPPLE} = 0.5V_{P-P}, f_{RIPPLE} = 120Hz, I_{LOAD} = 500mA		50	65		dB
Current Limit	V_{IN} = 7V, V_{OUT} = 0V C Grade: $V_{IN} = V_{OUT(NOMINAL)}$ + 1V or 2.3V (Note 12), ΔV_{OUT} = –0.1V MP Grade: V_{IN} = 2.35V (Note 12), ΔV_{OUT} = –0.1V	 ● ●	 520 520			 mA mA
Input Reverse Leakage Current	V_{IN} = –20V, V_{OUT} = 0V	●			1	mA
Reverse Output Current (Note 10)	LT1763-1.5 V_{OUT} = 1.5V, V_{IN} < 1.5V LT1763-1.8 V_{OUT} = 1.8V, V_{IN} < 1.8V LT1763-2.5 V_{OUT} = 2.5V, V_{IN} < 2.5V LT1763-3 V_{OUT} = 3V, V_{IN} < 3V LT1763-3.3 V_{OUT} = 3.3V, V_{IN} < 3.3V LT1763-5 V_{OUT} = 5V, V_{IN} < 5V LT1763 (Note 3) V_{OUT} = 1.22V, V_{IN} < 1.22V			10 10 10 10 10 10 5	20 20 20 20 20 20 10	μA μA μA μA μA μA μA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: The LT1763 regulators are tested and specified under pulse load conditions such that $T_J \approx T_A$. The LT1763 (C grade) is 100% tested at T_A = 25°C; performance at –40°C and 125°C is assured by design, characterization and correlation with statistical process controls. The LT1763 (MP grade) is 100% tested and guaranteed over the –55°C to 125°C temperature range.

Note 3: The LT1763 (adjustable version) is tested and specified for these conditions with the ADJ pin connected to the OUT pin.

Note 4: Operating conditions are limited by maximum junction temperature. The regulated output voltage specification will not apply for all possible combinations of input voltage and output current. When operating at maximum input voltage, the output current range must be limited. When operating at maximum output current, the input voltage range must be limited.

Note 5: To satisfy requirements for minimum input voltage, the LT1763 (adjustable version) is tested and specified for these conditions with an external resistor divider (two 250k resistors) for an output voltage of 2.44V. The external resistor divider will add a 5μA DC load on the output.

Note 6: Dropout voltage is the minimum input to output voltage differential needed to maintain regulation at a specified output current. In dropout, the output voltage will be equal to: $V_{IN} - V_{DROPOUT}$.

Note 7: GND pin current is tested with $V_{IN} = V_{OUT(NOMINAL)}$ or V_{IN} = 2.3V (C grade) or 2.35V (MP grade), whichever is greater, and a current source load. This means the device is tested while operating in its dropout region. This is the worst-case GND pin current. The GND pin current will decrease slightly at higher input voltages.

Note 8: ADJ pin bias current flows into the ADJ pin.

Note 9: $\overline{SHDN}$ pin current flows into the $\overline{SHDN}$ pin.

Note 10: Reverse output current is tested with the IN pin grounded and the OUT pin forced to the rated output voltage. This current flows into the OUT pin and out the GND pin.

Note 11: For the LT1763, LT1763-1.5 and LT1763-1.8 dropout voltage will be limited by the minimum input voltage specification under some output voltage/load conditions. See the curve of Minimum Input Voltage in the Typical Performance Characteristics.

Note 12: To satisfy requirements for minimum input voltage, current limit is tested at $V_{IN} = V_{OUT(NOMINAL)}$ + 1V or 2.3V (C grade) or 2.35V (MP grade), whichever is greater.

PIN FUNCTIONS (S8/DE12)

OUT (Pin 1/Pins 2, 3): Output. The output supplies power to the load. A minimum output capacitor of 3.3µF is required to prevent oscillations. Larger output capacitors will berequired for applications with large transient loads to limit peak voltage transients. See the Applications Information section for more information on output capacitance and reverse output characteristics.

NC (Pins 1, 4, 9, 12) DE12 Only: No Connect.

SENSE (Pin 2/Pin 5): Output Sense. For fixed voltage versions of the LT1763 (LT1763-1.5/LT1763-1.8/LT1763-2.5/LT1763-3/LT1763-3.3/LT1763-5), the SENSE pin is the input to the error amplifier. Optimum regulation will be obtained at the point where the SENSE pin is connected to the OUT pin of the regulator. In critical applications, small voltage drops are caused by the resistance (R_P) of PC traces between the regulator and the load. These may be eliminated by connecting the SENSE pin to the output at the load as shown in Figure 1 (Kelvin Sense Connection).

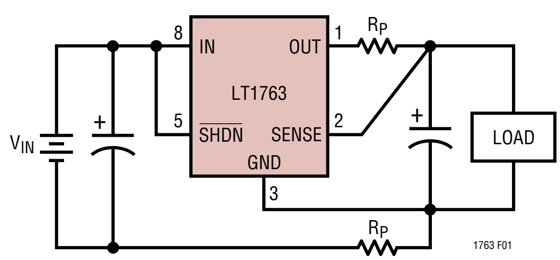


Figure 1. Kelvin Sense Connection

Note that the voltage drop across the external PC traces will add to the dropout voltage of the regulator. The SENSE pin bias current is 10µA at the nominal rated output voltage. The SENSE pin can be pulled below ground (as in a dual supply system where the regulator load is returned to a negative supply) and still allow the device to start and operate.

ADJ (Pin 2/Pin 5): Adjust. For the adjustable LT1763, this is the input to the error amplifier. This pin is internally clamped to ±7V. It has a bias current of 30nA which flows into the pin (see curve of ADJ Pin Bias Current vs Temperature in the Typical Performance Characteristics section). The ADJ pin voltage is 1.22V referenced to ground and the output voltage range is 1.22V to 20V.

BYP (Pin 4/Pin 6): Bypass. The BYP pin is used to bypass the reference of the LT1763 regulators to achieve low noise performance from the regulator. The BYP pin is clamped internally to ±0.6V (one V_{BE}). A small capacitor from the output to this pin will bypass the reference to lower the output voltage noise. A maximum value of 0.01µF can be used for reducing output voltage noise to a typical 20µV_{RMS} over a 10Hz to 100kHz bandwidth. If not used, this pin must be left unconnected.

GND (Pins 3, 6, 7/Pins 7, 13): Ground. The Exposed Pad (DE12) must be soldered to the PCB ground for rated thermal performance.

$\overline{SHDN}$ (Pin 5/Pin 8): Shutdown. The $\overline{SHDN}$ pin is used to put the LT1763 regulators into a low power shutdown state. The output will be off when the $\overline{SHDN}$ pin is pulled low. The $\overline{SHDN}$ pin can be driven either by 5V logic or open-collector logic with a pull-up resistor. The pull-up resistor is required to supply the pull-up current of the open-collector gate, normally several microamperes, and the $\overline{SHDN}$ pin current, typically 1µA. If unused, the $\overline{SHDN}$ pin must be connected to V_{IN}. The device will be in the low power shutdown state if the $\overline{SHDN}$ pin is not connected.

IN (Pin 8/Pin 10, 11): Input. Power is supplied to the device through the IN pin. A bypass capacitor is required on this pin if the device is more than six inches away from the main input filter capacitor. In general, the output impedance of a battery rises with frequency, so it is advisable to include a bypass capacitor in battery-powered circuits. A bypass capacitor in the range of 1µF to 10µF is sufficient. The LT1763 regulators are designed to withstand reverse voltages on the IN pin with respect to ground and the OUT pin. In the case of a reverse input, which can happen if a battery is plugged in backwards, the device will act as if there is a diode in series with its input. There will be no reverse current flow into the regulator and no reverse voltage will appear at the load. The device will protect both itself and the load.

APPENDIX D

LM3526 DATA SHEET

LM3526
Dual Port USB Power Switch and Over-Current Protection

General Description

The LM3526 provides Universal Serial Bus standard power switch and over-current protection for all host port applications. The dual port device is ideal for Notebook and desktop PC's that supply power to more than one port.

A 1 ms delay on the fault flag output prevents erroneous overcurrent reporting caused by in-rush currents during hot-plug events.

The dual stage thermal protection circuit in the LM3526 provides individual protection to each switch and the entire device. In a short-circuit/over-current event, the switch dissipating excessive heat is turned off, allowing the second switch to continue to function uninterrupted.

The LM3526 accepts an input voltage between 2.7V and 5.5V allowing use as a device-based in-rush current limiter for 3.3V USB peripherals, as well as Root and Self-Powered Hubs at 5.5V. The Enable inputs accept both 3.3V and 5.0V logic thresholds.

The small size, low R_{ON}, and 1 ms fault flag delay make the LM3526 a good choice for root hubs as well as per-port power control in embedded and stand-alone hubs.

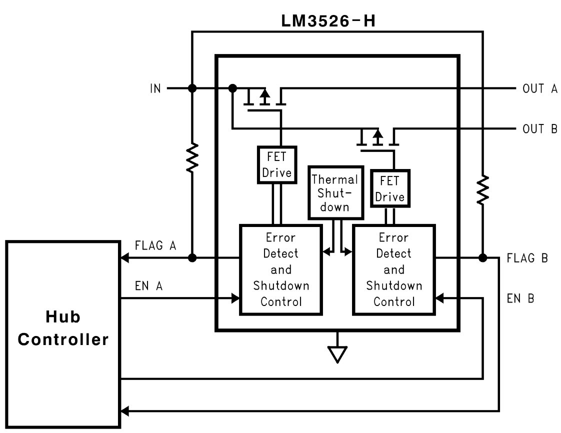
Features

- Compatible with USB1.1 and USB 2.0
- 1 ms fault flag delay filters Hot-Plug events
- Smooth turn-on eliminates in-rush induced voltage drop
- UL recognized component: REF# 205202
- 1A nominal short circuit output current protects PC power supplies
- Thermal shutdown protects device in direct short condition
- 500mA minimum continuous load current
- Small SO-8 package minimizes board space
- 2.7V to 5.5V input voltage range
- 140 mΩ Max. switch resistance
- 1 µA Max. standby current
- 200 µA Max. operating current
- Under-voltage lockout (UVLO)

Applications

- Universal Serial Bus (USB) Root Hubs including Desktop and Notebook PC
- USB Monitor Hubs
- Other Self-Powered USB Hub Devices
- High Power USB Devices Requiring In-rush Limiting
- General Purpose High Side Switch Applications

Typical Operating Circuit and Connection Diagram



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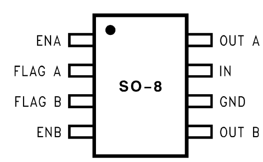

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LM3526-H

UL Recognized Component

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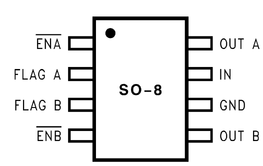

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LM3526-L

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	–0.3V to 6V
Output Voltage	–0.3V to 6V
Voltage at All Other Pins	–0.3V to 5.5V
Power Dissipation (T_A = 25˚C) (Note 2)	700 mW
T_{JMAX} (Note 2)	150˚C
Operating Junction Temperature Range	–40˚C to 125˚C
Storage Temperature Range	–65˚C to +150˚C
Lead Temperature (Soldering, 5 seconds)	260˚C
ESD Rating (Note 3)	2kV
ESD Rating Output Only	8kV

Operating Ratings

Supply Voltage Range	2.7V to 5.5V
Operating Ambient Range	–40˚C to 85˚C

DC Electrical Characteristics

Limits in standard typeface are for T_J = 25˚C, and limits in **boldface** type apply over the full operating temperature range. Unless otherwise specified: V_{IN} = 5.0V, $V_{\overline{EN}}$ = 0V (LM3526-L) or $V_{EN} = V_{IN}$ (LM3526-H).

Symbol	Parameter	Conditions	Min	Typ	Max	Units
R_{ON}	On Resistance	V_{IN} = 5V, I_{OUT} = 500mA, each switch		100	140	mΩ
		V_{IN} = 2.7V, I_{OUT} = 500mA, each switch		110	180	
I_{OUT}	OUT pins continuous output current	Each Output	**0.5**			A
I_{SC}	Short Circuit Output Current	Each Output (enable into Load) (Note 4) V_{OUT} = 4.0V V_{OUT} = 0.1V	0.5	1.2 1	1.9 1.5	A
OC_{THRESH}	Over-current Threshold			2.2	3.2	A
I_{LEAK}	OUT pins Output Leakage Current	$V_{\overline{EN}} = V_{IN}$ (LM3526-L) V_{EN} = 0V (LM3526-H)		0.01	10	µA
R_{FO}	FLAG Output Voltage	I_{FO} = 10 mA, V_{IN} = 5.0V		10	**25**	Ω
		I_{FO} = 10 mA, V_{IN} = 3.3V		11	**35**	
		I_{FO} = 10 mA, V_{IN} = 2.7V		12	**40**	
I_{EN}	$\overline{EN}$/EN Leakage Current	$V_{\overline{EN}}/V_{EN}$ = 0V or $V_{\overline{EN}}/V_{EN} = V_{IN}$	–0.5		0.5	µA
V_{IH}	$\overline{EN}$/EN Input Logic High	(Note 5)	**2.4**	1.9		V
V_{IL}	$\overline{EN}$/EN Input Logic Low	(Note 5)		1.7	**0.8**	V
V_{UVLO}	Under-Voltage Lockout Threshold			1.8		V
I_{DDOFF}	Supply Current	Switch-Off –40˚C ≤ T_J ≤ 85˚C		0.2	1 **2**	µA
I_{DDON}	Supply Current	Switch-On		115	200	µA
Th_{SD}	Over-temperature Shutdown Threshold	T_J Increasing, with no shorted output T_J Increasing, with shorted output (s) T_J Decreasing (Note 4)		150 145 135		˚C
I_{FH}	Error Flag Leakage Current	V_{flag} = 5V		0.01	1	µA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 2: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX} (Maximum junction temperature), θ_{JA} (junction to ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is $P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, which ever is lower. θ_{JA} = 150˚C/W.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. Enable pin ESD threshold is 1.7kV.

Note 4: Thermal Shutdown will protect the device from permanent damage.

Note 5: For LM3526-L, OFF is $\overline{EN}$ ≥ 2.4V and ON is $\overline{EN}$ ≤ 0.8V. For LM3526-H, OFF is EN ≤ 0.8V and ON is EN ≥ 2.4V.

AC Electrical Characteristics

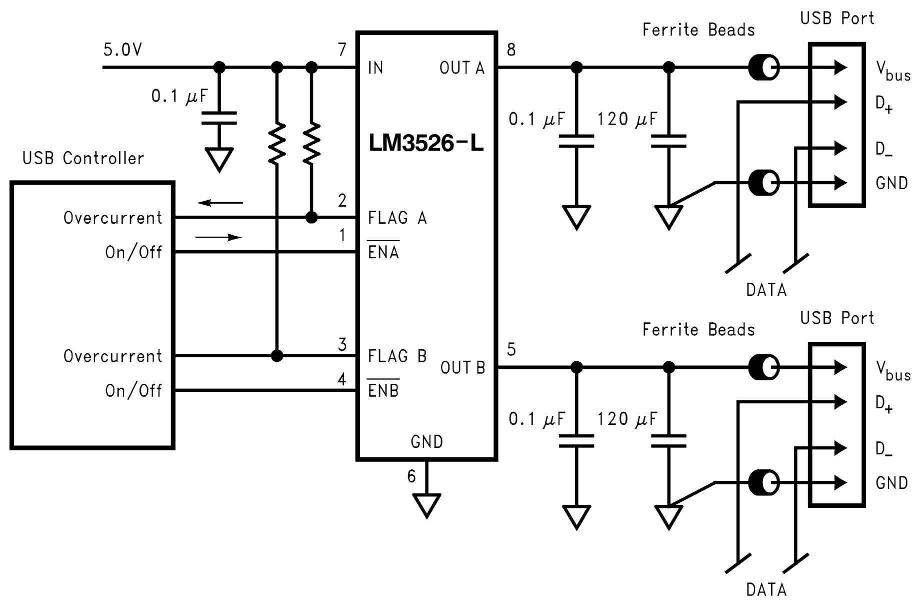
Limits in standard typeface are for T_J = 25˚C, and limits in **boldface** type apply over the full operating temperature range. Unless otherwise specified: V_{IN} = 5.0V.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_r	OUT Rise Time	R_L = 10Ω		100		µs
t_f	OUT Fall Time	R_L = 10Ω		5		µs
t_{ON}	Turn on Delay, $\overline{EN}$ to OUT	R_L = 10Ω		150		µs
t_{OFF}	Turn off Delay, $\overline{EN}$ to OUT	R_L = 10Ω		5		µs
t_{OC}	Over Current Flag Delay	R_L = 0		1		ms

Pin Description

Pin Number	Pin Name	Pin Function
1, 4	$\overline{ENA}$, $\overline{ENB}$ (LM3526-L) ENA, ENB (LM3526-H)	Enable (Input): Logic-compatible enable inputs.
2, 3	FLAG A FLAG B	Fault Flag (Output): Active-low, open-drain outputs. Indicates overcurrent, UVLO or thermal shutdown. *See application section for more information.
6	GND	Ground
7	IN	Supply Input: This pin is the input to the power switch and the supply voltage for the IC.
8, 5	OUT A OUT B	Switch Output: These pins are the outputs of the high side switch.

Typical Application Circuit



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