

# Tower System Power Supply Options

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## 1 Overview

The Freescale Tower System is a modular development platform that enables advanced development through rapid evaluation and prototyping. Featuring multiple development modules, the Freescale Tower System provides designers with building blocks for entry-level to advanced application development. A designer can select processor modules within the range of 8- to 32-bit microcontrollers, peripheral modules, and Tower Plug-ins, and connect them together using the Tower Elevator module in order to begin developing an application in a fast and easy manner. Moreover, the developer can create their own Tower System module, or use the prototype module for customer circuits.

The power supply is an important aspect of any electronic system. The construction of a power source is the main influence on the stability of the system. The Freescale Tower System provides several powering options. This application note will describe the power supply options of the Tower System, explain some uncertainties, and warn the developer of limitations.

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## 2 Tower System power sources

The Freescale Tower System can be powered by several options. Every option has its own advantages and limitations which are described briefly as follows.

Main available power options are:

- powering from the Tower System Elevator module (USB connector, terminal block),
- powering from modules by on-module USB connector (part of OSBDM, CMSIS-DAP,...),
- or its own power source.

Main power supply voltages within the Tower System are

- 5 V—main power supply voltage within the Tower System supplied externally and filtered only
- 3.3 V—regulated voltage power source for microcontrollers and other circuits

### Other voltages

Depending on the module and components, different high and low voltages are needed for special purposes. For example, 1.5 V is needed to supply DDR memories, 1.2 V to supply the core, or higher levels for H-bridge for motor control. These voltages have to be gained within a given module or have to be supplied from an external power source.

### Common limitations

One of the common limitations is USB maximum current which is 500 mA for USB 2.0, depending on the port type. The side Tower Elevator connectors are used for interconnecting the modules. Maximum current limitation for the Tower Elevator connector is 2.5 A, but not on all the pins at a time. The maximum number of cycles (plug in/plug out of the Tower module) limitation is not exactly defined. Number of cycles is only one digit value for safe work.

### Tower System modules classification

There are two types of the Tower System modules (not boards) from power supply point of view:

- Self-powered modules: These modules can create all necessary voltage levels from one main power supply, for example, one USB connector. All Tower System controller modules are self-powered modules.
- Passive modules: These modules rely on external power supply source. They do not have a voltage regulator on a module. Most of Tower System peripheral modules are passive modules. They are taking power from the Tower System Elevator module.

## 2.1 Tower System power supply pins

The Tower System Elevator module (the elevator modules) is compound from the primary elevator and the secondary elevator. The elevator modules contain 82 pins in 4 columns. They are divided in rows from A to D. Rows A and B are placed on the primary elevator. Rows C and D are placed on the secondary elevator. Every row contains power pins. The following table lists the summary of power pins.

Elevator Primary Connector							
Pin #	Side B			Pin #	Side A		
	Name	Description	I/O		Name	Description	I/O
B1	5V	5.0V Power	–	A1	5V	5.0V Power	–
B2	GND	Ground	–	A2	GND	Ground	–
B3	3.3V	3.3V Power	–	A3	3.3V	3.3V Power	–
B4	ELE_PS_SENSE	Elevator Power Sense	I/O	A4	3.3V	3.3V Power	–
B5	GND	Ground	–	A5	GND	Ground	–
B6	GND	Ground	–	A6	GND	Ground	–
Mechanical Key							
B26	GND	Ground	–	A26	GND	Ground	–
B31	GND	Ground	–	A31	GND	Ground	–
B36	3.3V	3.3V Power	–	A36	3.3V	3.3V Power	–
B49	GND	Ground	–	A49	GND	Ground	–
B65	GND	Ground	–	A65	GND	Ground	–
B81	GND	Ground	–	A81	GND	Ground	–
B82	3.3V	3.3V Power	–	A82	3.3V	3.3V Power	–
Elevator Secondary Connector							
Pin #	Side D			Pin #	Side C		
	Name	Description	I/O		Name	Description	I/O
D1	5V	5.0V Power	–	C1	5V	5.0V Power	–
D2	GND	Ground	–	C2	GND	Ground	–
D3	3.3V	3.3V Power	–	C3	3.3V	3.3V Power	–
D4	ELE_PS_SENSE	Elevator Power Sense	I/O	C4	3.3V	3.3V Power	–
D5	GND	Ground	–	C5	GND	Ground	–
D6	GND	Ground	–	C6	GND	Ground	–
Mechanical Key							
D26	GND	Ground	–	C26	GND	Ground	–
D31	GND	Ground	–	C31	GND	Ground	–
D36	3.3V	3.3V Power	–	C36	3.3V	3.3V Power	–
D49	GND	Ground	–	C49	GND	Ground	–
D65	GND	Ground	–	C65	GND	Ground	–
D81	GND	Ground	–	C81	GND	Ground	–
D82	3.3V	3.3V Power	–	C82	3.3V	3.3V Power	–

Figure 1. Power pins summary

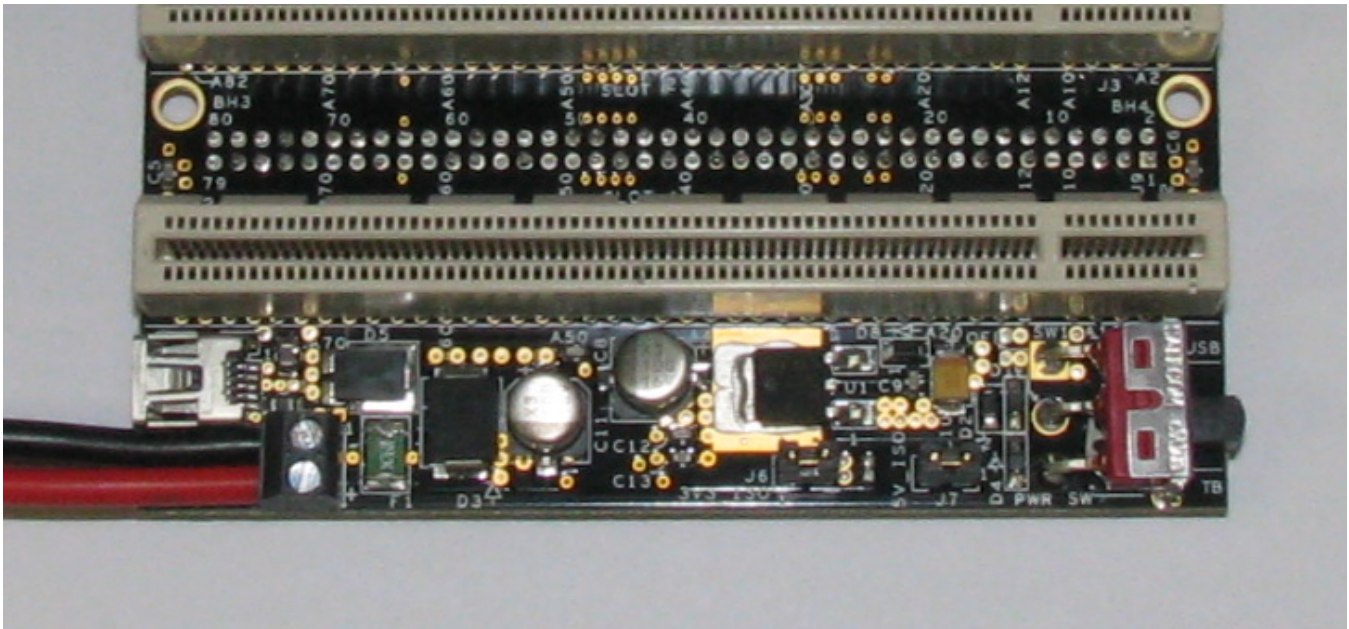
**NOTE**

The secondary elevator is powered only when the self-powered Tower System module is present. The self-powered Tower System module creates a connection between the primary and secondary elevator. For example, passive/peripheral TWR-SER Tower System module does not connect 5 V, 3V3 and ELE\_PS\_SENSE. It connects only GND signals.

## 2.2 Power supply from the Tower System Elevator module

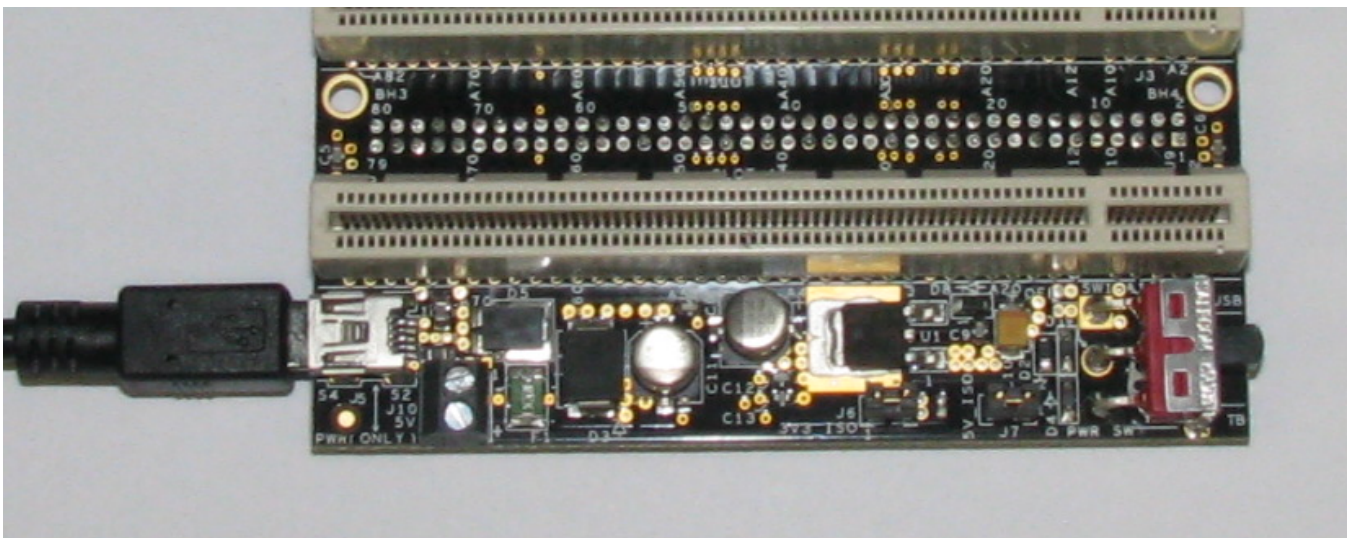
Tower System Elevator modules are used for interconnecting and powering tower modules. The primary elevator consists of a power supply circuit with 3.3 V linear voltage regulator. The main option to supply power to the Tower System is with the primary elevator.

The power source connectors are located at the bottom part of the primary elevator. The power supply can be supplied either through the USB connector or the terminal block. The source can be selected using the three-position switch on the right side of the primary elevator.



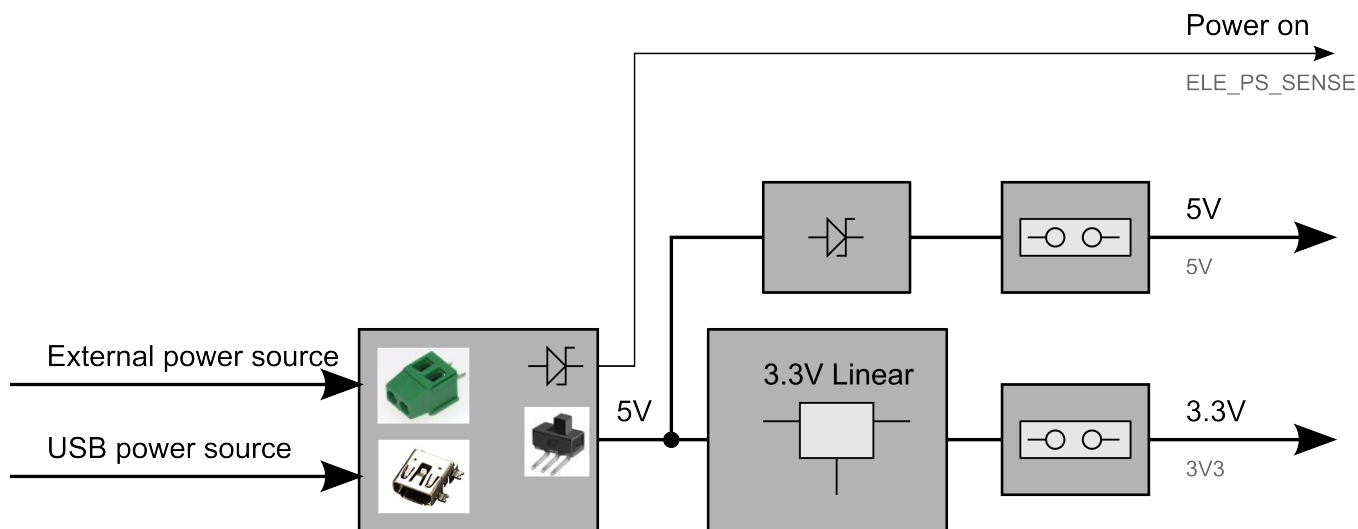
**Figure 2. Tower System primary elevator using external power source**

Figure 2 shows powering from the external power source. The three-position switch is at bottom position. Terminal block is used.



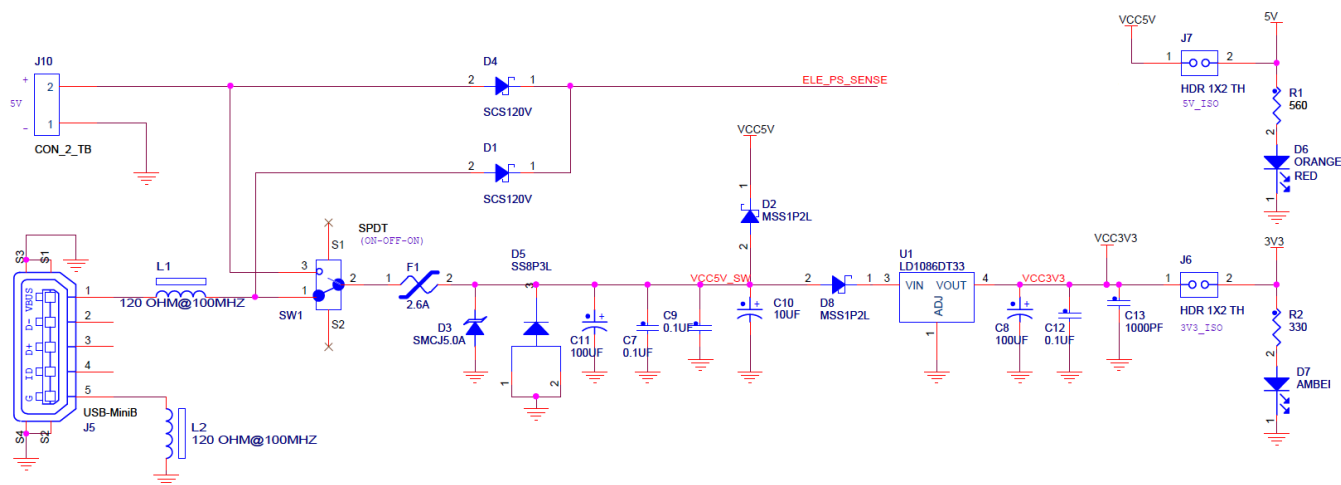
**Figure 3. Tower System primary elevator using USB cable power source**

Figure 3 shows powering from the USB cable power source. The three-position switch is at top position. The mini USB connector is used.



**Figure 4. Tower System primary elevator power source block diagram**

The Tower System primary elevator power supply source contains two connectors for connecting external power source, the three-position switch for selection of the power source, linear 3.3 V voltage regulator, two isolation jumper headers, power present indication LEDs, and the power present information signal. The block diagram is shown in Figure 4.



**Figure 5. Tower System primary elevator power source schematic**

The primary elevator power source schematic (see Figure 5) shows that the circuit is equipped with the reverse current protection using Schottky diode D2. Linear voltage regulator U1 is not equipped with integrated reverse current protection. The circuit includes filtering coils, fuse F1, overvoltage protection D3, and ELE\_PS\_SENSE signal circuit [ 2 ].

5 V voltage is indicated by the red LED (schematic symbol 5 V). 3.3 V voltage is indicated by the orange LED (schematic symbol 3V3). Both voltage sources can be isolated from the rest of the Tower System by jumpers.

## 2.2.1 Schematic signals description

- **ELE\_PS\_SENSE**—indicates that the elevator modules are powered from the primary elevator power source.

## Lower System power sources

- **5 V**—Main power supply voltage within the Tower System. The power supply is taken from the external power source. The power source is filtered and protected by fuse F1 and by transistor D3 for the voltage level and by Schottky diode D8 for polarity. The voltage level varies due to USB voltage level tolerance and polarity protection.
- **Ground**—is the most important signal within the Tower System. The users must be careful while handling especially in precise analog measurements, high frequencies, and high currents.

## 2.2.2 Parameters

### USB 5V supply:

The output voltage level is given in the front of all by a USB specification (USB 1.1, 2.0, or 3.0). The voltage level of a power source shall be within  $\pm 5\%$  limit, that is, in a range of 4.75–5.25 V for the high-power port and 4.40–5.25 for the low-power port, according to the USB 2.0 specification [3]. The maximal current is also limited by a USB specification and moreover depends on a driver request and an operating system. For example, a connected USB device gets 100 mA initially and can get up to 500 mA after receiving the driver request. The maximal current is also given by an USB port type—more than 100 mA for low-power Hub Ports and more than 500 mA for a high-power Hub Ports. Some operating systems do not fulfill this process and supply maximal current without request. See the Universal Serial Bus Specification [3].

In the case of an external power source (terminal block connection), current is limited by the internal fuse, which is 2.6 A and the power supply unit.

#### NOTE

The user must check the USB host limitation and remember the cable voltage drop.

### 3V3 (3.3 V) supply:

Parameters are limited by on-module linear voltage regulator. LD1086 linear 3.3 V voltage regulator is used in current revision. The load regulation is typically 1 mV for 25°C (maximum 16 mV). The maximal current for this regulator is 1.5 A.

### Input voltage:

The voltage drop of the integrated regulator  $V_D$  is 1.1 V for 100 mA (1.3 V typically/1.5 V maximally for 1.5 A). For minimal input voltage Schottky diode, the voltage drop  $V_{D8}$  needs to be considered. The voltage drop can vary from 0.26–0.45V. The user must be careful when using USB power supply and check if the linear voltage regulator works correctly. By defining Equation 1,  $V_{cc5Vsw}$  is sum of the output voltage and the voltage drops.

$$V_{cc5Vsw} = V_{3V3} + V_D + V_{D8}$$

#### Equation 1.

For example, for 100 mA and 25°C, the minimal power supply voltage is:

$$V_{cc5Vsw} \text{ minimal} = 3.3 + 1.1 + 0.33 = 4.73 \text{ V}$$

And for 500 mA and 25°C, the minimal power supply voltage is:

$$V_{cc5Vsw} \text{ minimal} = 3.3 + 1.15 + 0.39 = 4.84 \text{ V}$$

Though the normal voltage drop  $V_D$  on lower currents is lower; there are additional drops on USB cable, Tower Elevator module and internal source paths in the modules. The user must be careful when using USB power supply and check if the linear voltage regulator works correctly, so 3.3 V is stable within the current range used. Especially check analog references.

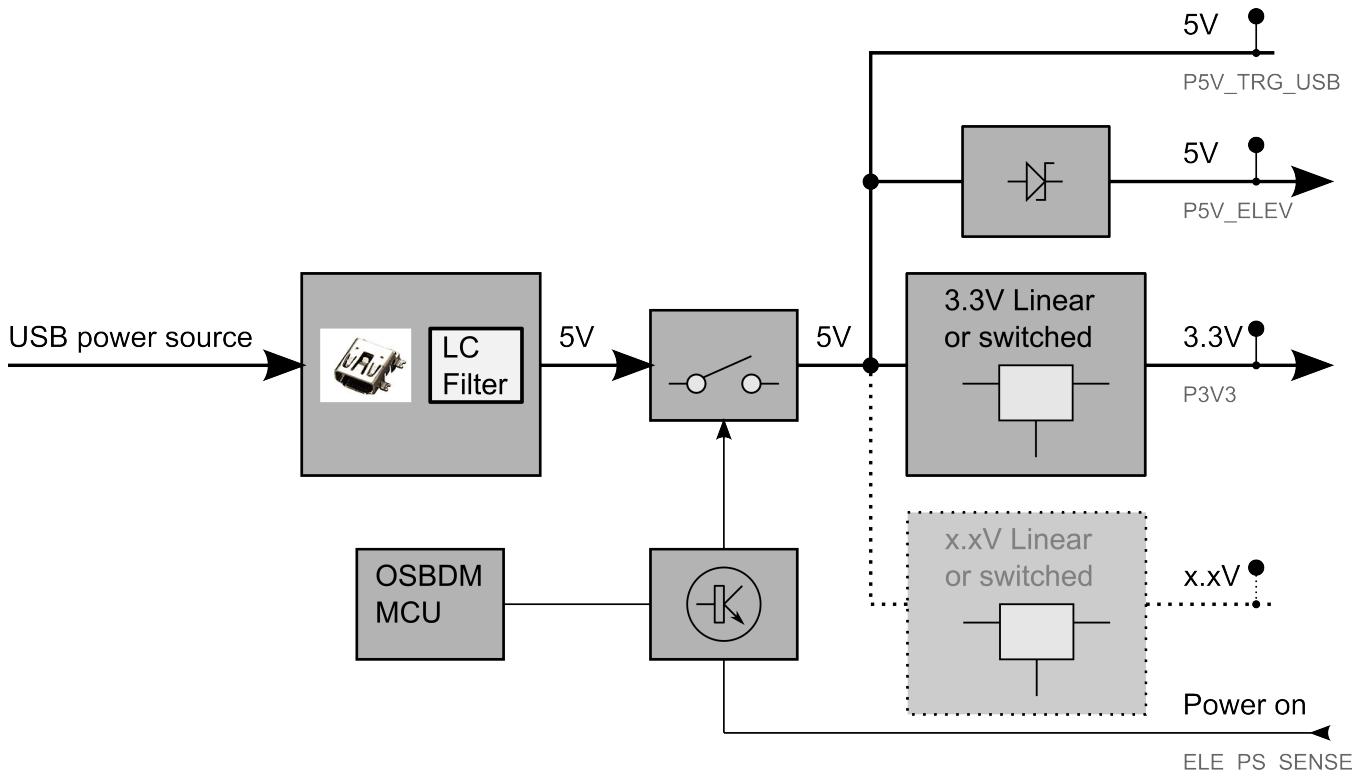
#### NOTE

Always check voltage levels from the primary elevator especially P3V3 signal for voltage level sensitive circuits.

## 2.3 Tower System power supply from on-module USB connector

Standalone Tower System modules can be powered using on-module power supply source. In this case, elevators are not needed for power supply.

The block diagram is shown in [Figure 6](#). Once a tower module is plugged-in into USB, power source is filtered and on-module debugger circuit is powered up. If a device is successfully recognized by the host operating system, then the maximal current from the host can be increased. On-module debugger circuit then enables the power supply for rest of the module by turning on the electronic switch. The electronic switch output usually enables 5 V voltage branch which supplies 3.3 V linear or switched regulator and the module starts working. Modern microcontroller modules also need lower voltages, for example 1.5 V to supply DDR memories or 1.2 V to supply the core.

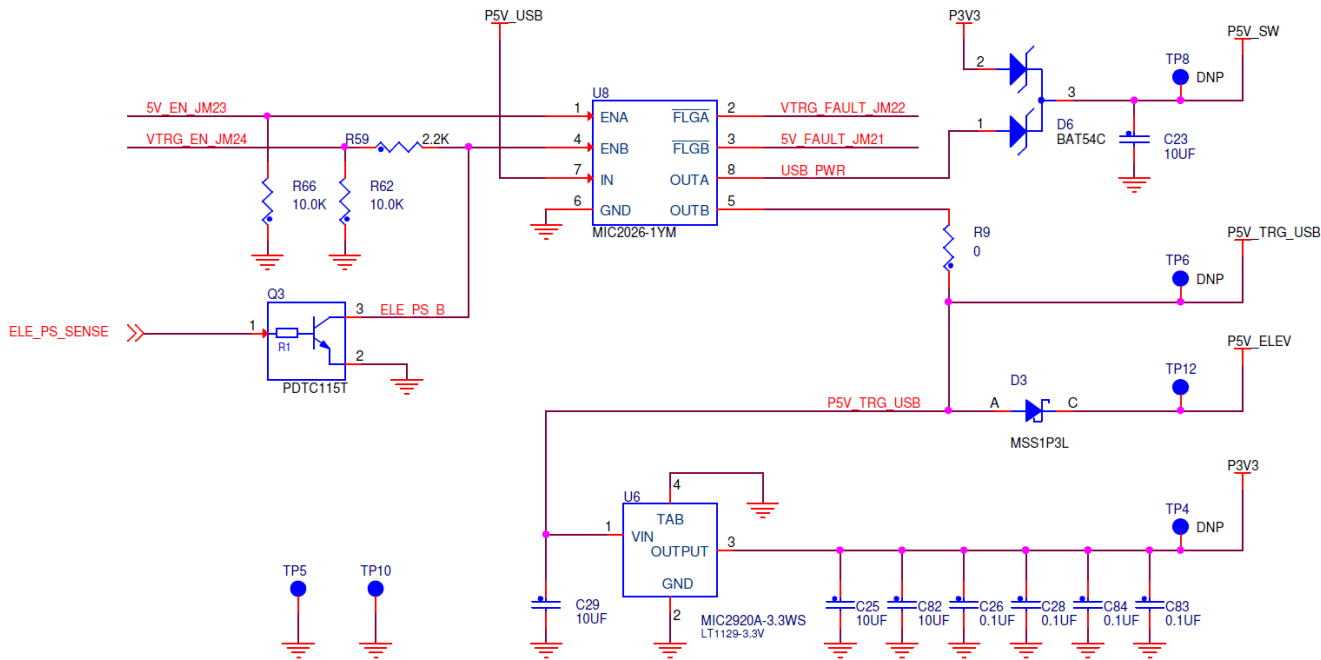


**Figure 6. Tower System module power source block diagram**

The elevators are essential in the case when other tower modules need to be connected to the main control module—for example—the serial module. In this case, power could be supplied from the elevator modules or from the main control module. The power supply sources are then controlled using dedicated signal. The power supplied through the elevator modules takes precedence.

On-module power sources are controlled by two ways:

- On-module debug circuit (OSBDM, OSJTAG, Open-SDA, CMSIS-DAP, ...)
- External control signal ELE\_PS\_SENSE



**Figure 7. Power part of TWR-PXN20 Tower module**

Figure 7 displays example of the power part of the Tower System Module (TWR-PXN20) [4, 5]. ELE\_PS\_SENSE signal from the elevator modules handles Transistor Q3. If the signal is low, then the module power sources are used. The power source from on-module USB connector is represented by P5V\_USB label. The power source (5 V level) is connected to U8 electronic switch. On-module OSBDM circuit enables the power supply for rest of the module by rising VTRG\_EN\_JM24 signal connected to ENB input of U8 electronic switch. Then, OUTB output (pin 5) is connected to IN input (pin 7) of U8 electronic switch and U6 3.3 V voltage regulator is powered and the module power source supplies P5V\_ELEV and P3V3. The power is supplied to the module and through the elevator modules to other connected tower modules.

If powered USB cable is connected to the primary elevator, then ELE\_PS\_SENSE signal is high, Q3 is open and B part of U8 switch and U6 voltage regulator are disabled. The module is then powered from the primary elevator. The power supplied through the elevator modules takes precedence.

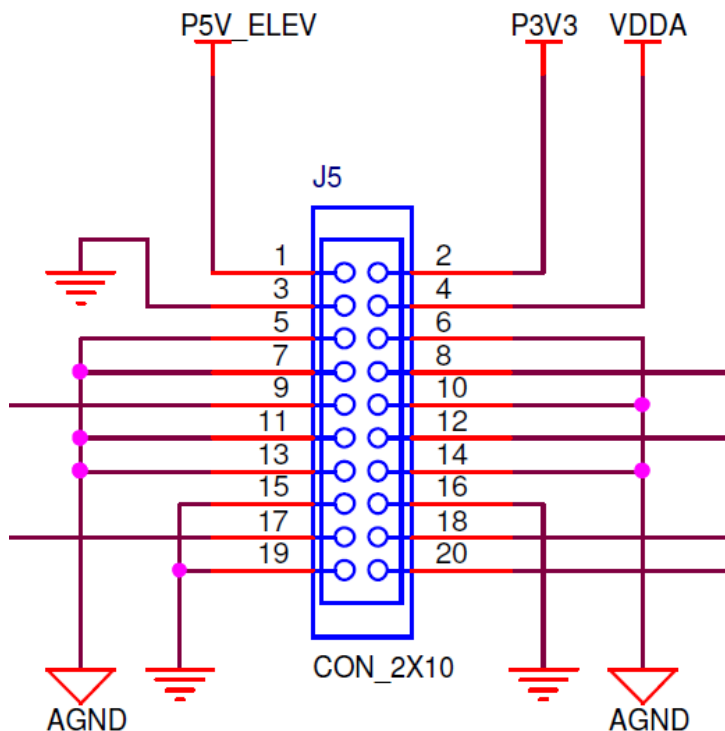
**NOTE**

If the power supply on the primary elevator is also present, then ELE\_PS\_SENSE is high which will disable the 3.3 V voltage regulators that supply 5 V and 3V3 lines to the Tower elevators (that is, if the signal is high, all the Tower System modules shall stop supplying energy to the Tower elevators).

**2.3.1 Tower TWRPI**

Tower Plug-In (TWRPI) is a way to extend the functionality of the Tower System module by plugging a small module into the TWRPI socket. There are different types of TWRPI modules which are supplied by 5 V and 3.3 V.





**Figure 8. Correct method of powering TWRPI sub module**

An example of TWRPI socket schematic is shown in [Figure 8](#). Some tower modules connect pin 1 to 5 V voltage from the Tower System Elevator module (symbol P5V\_ELEV) which is after polarity protecting Schottky diode. It means that there is no 5 V level, but 5 V minus the diode voltage drop (0.2–0.5 V depending on the current). On the other hand, some tower modules connect to 5 V without diode protection (symbol P5V\_TRG\_USB). [6, 7]

**NOTE**

The user must remember the 5 V voltage level uncertainty.

## 2.3.2 Parameters

Parameters for this power options are limited by USB host limits and module design.

## 2.4 Own power supply source

Some devices need different voltage levels of the power supply source, especially for high-power applications like motor control or power control. For such applications, the device's own power supply has to be created. For this case, TWR-PROTO Prototype module can be used, or its own module could be created.

From the power supply point of view, the user must ensure that:

- Ground is well connected—respecting analog and digital one point grounding rule.
- ELE\_PS\_SENSE signal is respected for turning off the module power source in the case of supplying power to the Tower elevators.
- 3.3 V module source is connected to P3V3 Tower elevator pin.

## Tower System power sources

- 5 V module source is connected to P5V Tower elevator pin.
- Ensure ability of a voltage regulator to resist voltage on output without voltage on input, which can happen if the power source is not turned off by ELE\_PS\_SENSE signal.

### NOTE

Before starting, see AN4390: Creating your own Tower Module [8].

## 2.5 Powering analog part of the Tower System

Current microcontrollers are equipped with analog-to-digital (A/D) converters usually with 10- to 12-bit precision. Each bit of a digital number represents very small voltage value. A precise reference voltage is essential for obtaining the right converted value.

For example: For a 10-bit ADC, the analog voltage range  $V_A$  is 3.3 V. The number of digital levels  $N_{ADC}$  for 10 bits resolution is  $2^{10} = 1024$  digital levels. See the following equation.

$$V_{LSB} = V_A / (N_{ADC} - 1) = 3.3 / 1023 = 3.22 \text{ mV}$$

### Equation 2.

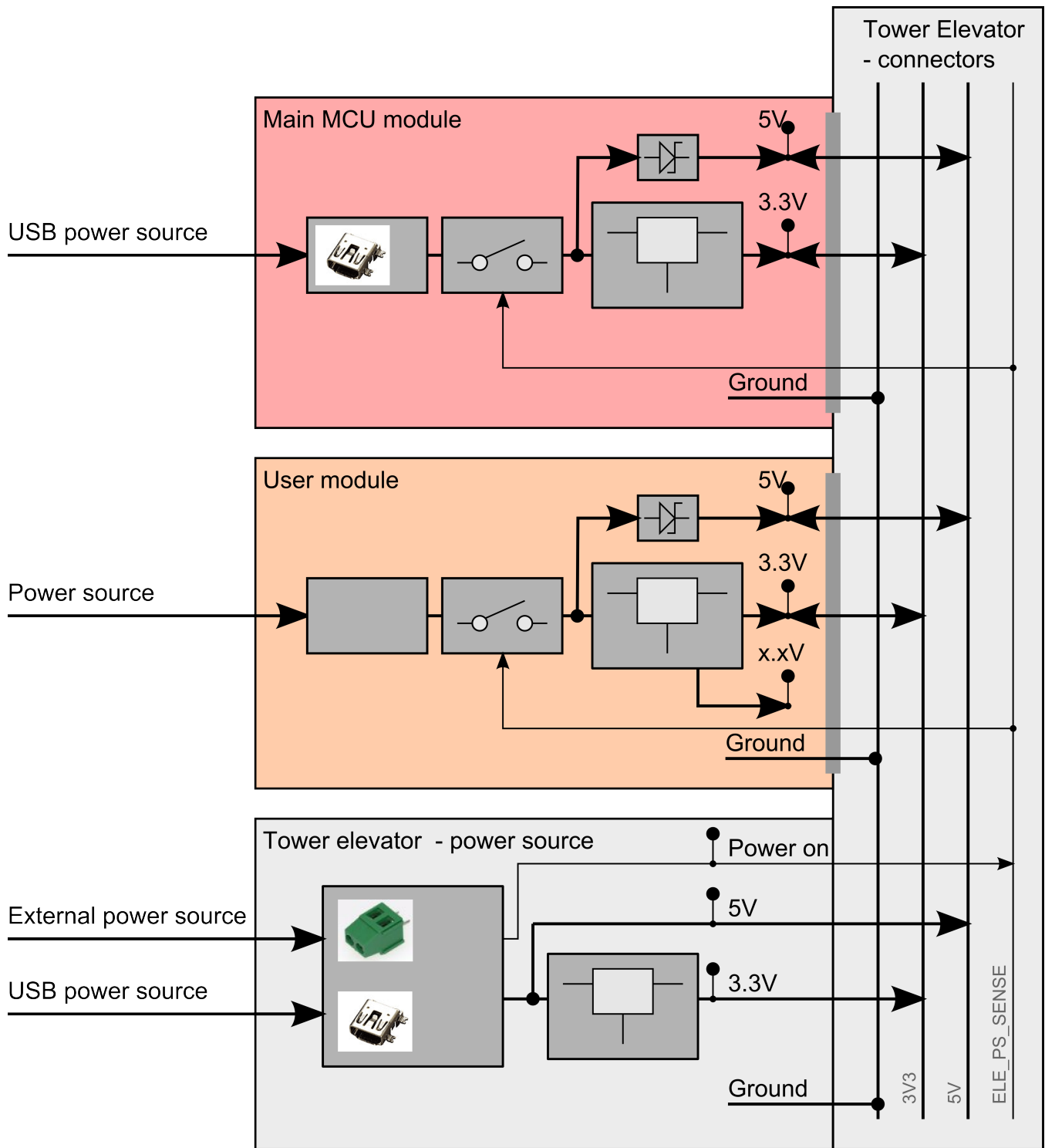
From the equation given above, it can be calculated that 10-bit ADC on 3.3 V range gives the resolution of 3.22 mV per bit. This is quite a small value as compared to expected precision of the power supply voltage or the reference voltage. Due to voltage drops on cables, lines and PCB lines, the Tower System voltages (5 V and 3.3 V) are not precise enough.

### NOTE

The user must be careful while using 5 V and 3V3 as a reference voltage for analog circuits. Use a voltage reference circuit for high-precision applications.

## 2.6 Overall power block diagram

A complete tower system usually consists of several tower modules: a main control tower module, or the MCU module (for example, TWR-K60-512, TWR-PXN20, TWR-VF65,...), and from 1–3 peripheral or customer modules (for example, TWR-SER, TWR-SER2).



**Figure 9. Power block diagram of a complete Tower System**

The block diagram of a complete tower system is depicted in [Figure 9](#). In the figure, the main MCU module is represented by the red rectangle, the user module is represented by the orange rectangle and the primary elevator is represented by gray color rectangles. The primary elevator is on right side (shown as the right grey color rectangle) and its integrated power source is represented by the bottom grey color rectangle. If powered USB cable is plugged-in to the USB power source of the main MCU module, the on-module circuits filter the power source and create power supply voltages 5 V and 3.3 V. They are used

## Summary

within the main control module and also supply rest of the Tower System through the Tower System Elevator module. If powered USB cable is not connected, the module can be supplied from the elevator modules shown as bidirectional arrows in the figure.

Similar situation is on the user module. It could have its own power supply or could rely on the supply of the elevator modules. If the module needs other voltage, then it has to be created on the module—the Tower System supports only 3.3 V and 5 V.

If the primary elevator is powered from an external power source or USB power source, then ELE\_PS\_SENSE signal is generated and the signal is broadcasted within the Tower System. Other modules plugged-in shall stop supplying the power to the elevator modules to avoid contention.

## 3 Summary

This application note has provided the developer an overall description of powering within the Tower System, possible power supply options, and limitations. With the understanding that power supply is the most important element of any electronic system, the developer should now be able to use the Tower system safely within all power requirement scenarios.

## 4 Reference documents

The documents listed below (available on [freescale.com](http://freescale.com)) can be referenced for more information about the Tower System and other parts included in this application note.

1. Tower system web page, [freescale.com/tower](http://freescale.com/tower)
2. Tower system primary elevator power source scheme, [Primary Elevator Schematics](#)
3. Universal Serial Bus Specification, [usb.org/developers/docs](http://usb.org/developers/docs)
4. TWR-PXN20: Power Architecture® PXN20 MCU Tower System Module, [freescale.com/TWR-PXN20](http://freescale.com/TWR-PXN20)
5. TWR-PXN20 Schematic PDF file, [TWR-PXN20 Schematics](#)
6. TWR-K60N512: Kinetis K60 Tower System Module, [TWR-K60N512](#)
7. TWR- K60N512 Schematics PDF file, [TWR-K60N512 Schematics](#)
8. AN4390: [Creating Your Own Tower Module](#)



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