Our robot, BUD-E is designed to be mobile without relying on A.C power from the wall sockets during operation. Figure 1 shows the main components of the robot that draws or supplies electrical power.

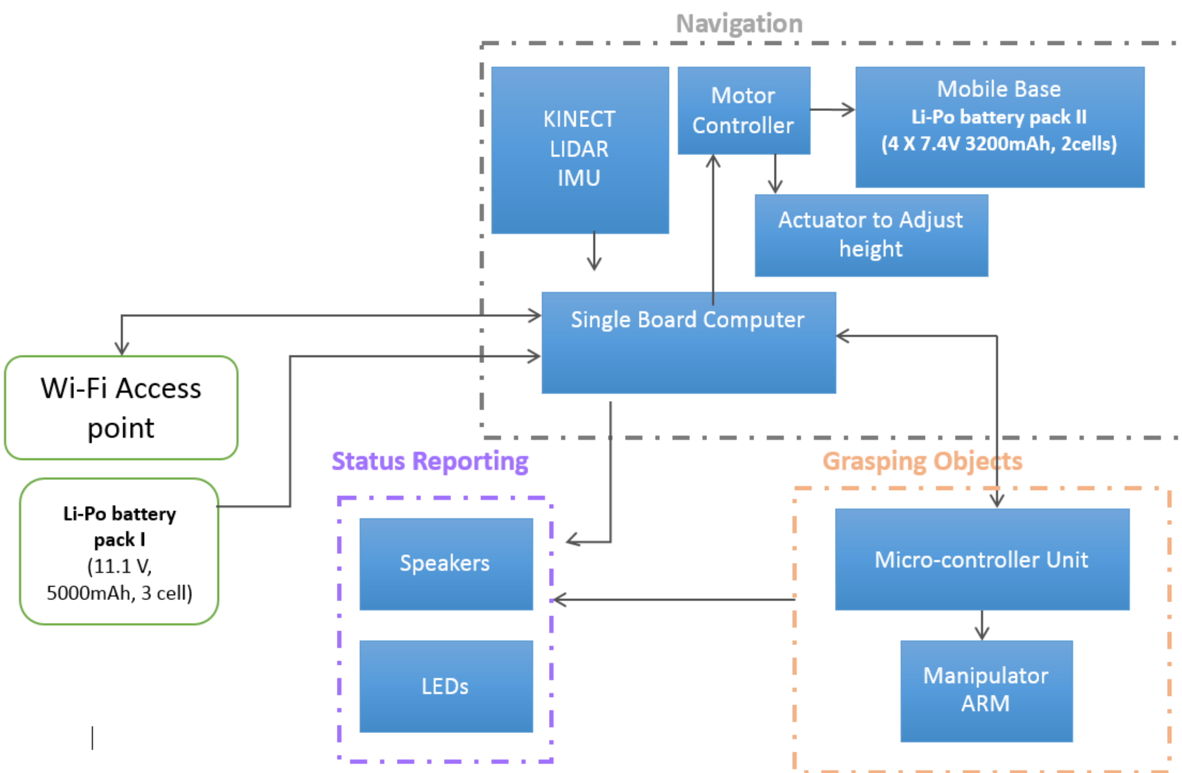

Figure 1 Subsystems that draw or require power.

Sources of Power:

1. **Li-Po Battery pack II** (in the mobile base)

   The battery pack in the mobile base (Mini-Dora) is used for powering the main drive train comprising of 2 brushed DC motors and the posture drive system comprising of 2 DC geared motors. The power bank has 4 batteries. Each battery has 2 Cells each with a cell voltage of 3.7 V giving a battery voltage of 7.4 V. It has a 3200mAh at a nominal discharge rate of 2C.

2. **Li-Po Battery pack I**

   This battery pack supplies power to the rest of the robot including the sensor head and the manipulator arm. This power bank has a 5000mAh capacity at 11.1V (3 cells) with a constant discharge rate of 25C and a maximum burst capacity of 35C.

Subsystem level power requirements:

The navigation subsystem includes the sensor head which has a Microsoft Kinect for X-box 360, a Hokuyo and an IMU.

- **Kinect for xbox 360**
  Requires a regulated 12V DC supply with a peak current requirement of 1A and a nominal current requirement of 600mA-800mA.
- **Hokuyo URG-04LX**
  Operates at a voltage range of 4.75V-5.25V with a peak current requirement less than 500mA. This makes it easier to power the LIDAR. It uses a single USB port for both data and power.
- **IMU**
  We are planning to use the 9DoF Razor IMU (SEN 10736). It has an internal regulator which regulates any power supplied to it through the white JST connector to a voltage at 3.3V. The IMU is shown in figure. It operates with any input voltage in the range of 3.5V - 16 V DC.

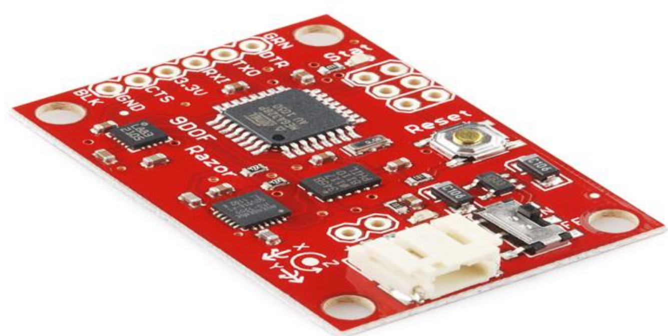

Figure 2 Razor IMU

The mobile base (Mini-Dora) has a well-designed power system which powers two Maxon DC motors for posture adjustments and four brushed DC motors through slip rings for the main drive system. An electrical wiring diagram of the base is shown in figure 3. Two of the batteries in the battery pack II are connected in series to get a terminal voltage of 14.8V. The other two batteries are connected in series too. This configuration of the batteries is then connected in parallel to achieve a common voltage level of 14.8 V but at twice the current capacity. This means the overall current capacity of the system is at 6400mAh at a voltage level of 14.8 V. This powers each of the EVX-3014s which are the Electronic Speed Controllers (ESC). The specifications of the ESC is detailed in figure 4.

figure 3.

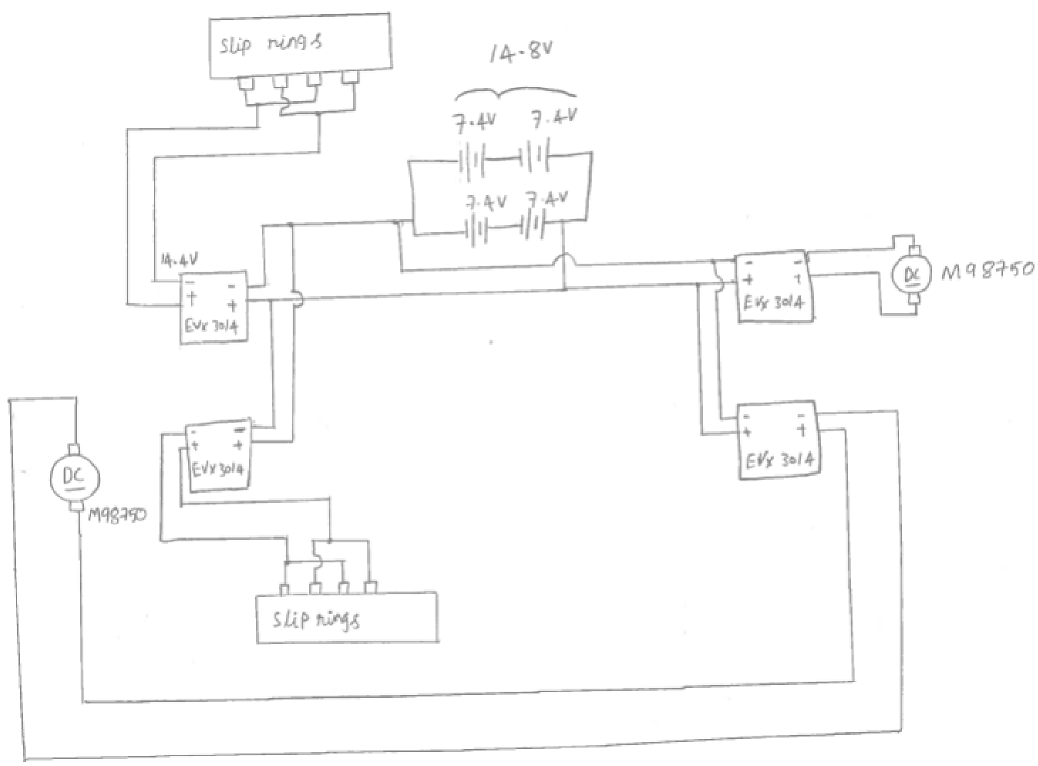

Figure 3 Wiring diagram of the mobile base.

Input Voltage (1.2VDC/cell)	12 cells (14.4 volts DC)
Case Width	1.75 inches
Case Depth	2.17 inches
Case Height	0.85 inches
Weight (w/o heat sinks)	3.5 ounces
Motor Limit	19 turns minimum (550 size)
On-Resistance–Forward (@Trans)	0.006 Ω
On-Resistance–Reverse (@Trans)	0.006 Ω
Rated Current–Forward	160 amps
Rated Current–Reverse	160 amps
Braking Current	320 amps
Continuous Current (@100°F amb.)	30 Amps
Reverse Delay (after Smart Braking)	Zero Seconds
BEC Voltage	5.0 volts DC
BEC Current	1.5 amps
Power Wire	14G / 9”
Input Harness	26G / 9”
Switch Harness	26G / 6”
Transistor Type	HYPERFET III
PWM Frequency	1000 Hertz
Protection	Thermal Shutdown

Figure 4 Specifications of EVX-3014.

There are 4 EVX-3014s in the base. Two of these power the two posture drive DC motors (the Maxon motors) and the two others drive 2 brushed DC motors through the slip rings as shown in figure 3.

We are considering a **scissor lift** mechanism to adjust the height of the robot. One of the probable off-the solution which we might use requires a 18-24V DC supply with a nominal current draw between 1A-5A depending on the load.
The Single Board Computer that we are considering is the Arndale development board with a quad core ARM Cortex A15 processor. It has a low TDP compared to other Intel based ITXs. It requires a 5V DC supply at a peak current draw of 3.5 A. The board has an internal low dropout voltage regulator which accepts input voltage levels between 5-8V. The nominal current draw with a Kinect, Hokuyo and an Arduino is expected to be in the range of 2A. Which means a power requirement of 5VX 2A=10 Watts.

We plan to have a Manipulator ARM with 3 Dynamixel AX-12A servos. They operate with an input voltage between 9 and 12V with 11.1 being the recommended voltage. They have a stall torque of 1.5Nm at 12V and 1.5 A. This servo with a weight at mere 53.5 gms and a high torque with a fine resolution of 0.29 degrees were the deciding factor for choosing this servo.

Overall, we require two RISC microcontrollers for interfacing with various low-level hardware. One ARM cortex M3 based STM microcontroller for exclusively controlling the manipulator arm and an Arduino for controlling the height of the torso and for driving the status indicating LEDs. The two boards will be powered using the single board computer. The speaker used for communicating the user will be driven using the stereo jack on the single board computer.

Manipulator Arm control and power

The 3 high torque dynamixel servo motors which constitute the core of the manipulator arm requires a separate controller. The specification of the manipulator controller are shown in Table 1. The STM 32 MCU connects to the single board computer (the USB host) and controls the dynamixel servos using a TTL bus. The control architecture is shown in figure 5.

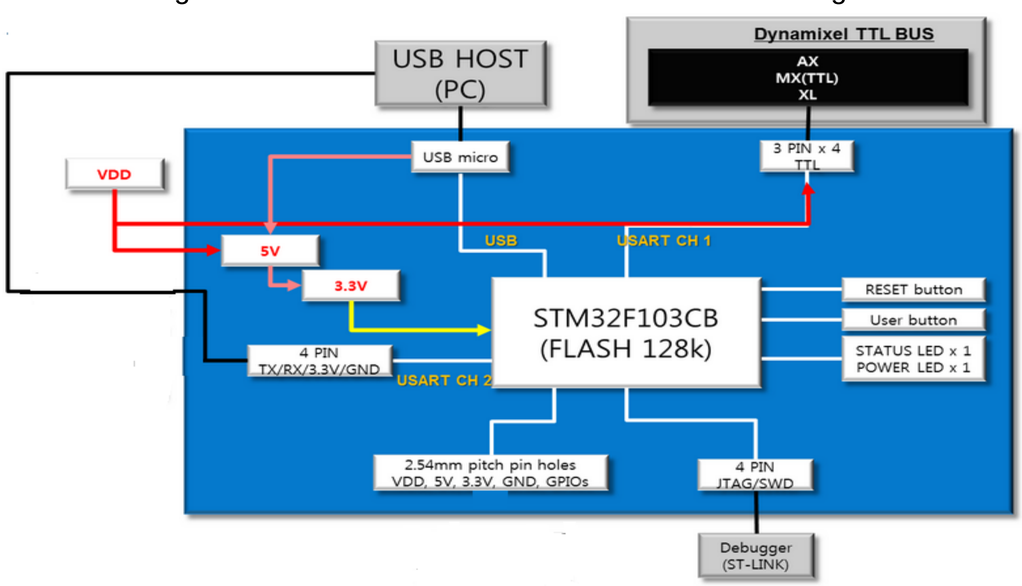

Figure 5 Manipulator control architecture.

Table 1 Specifications of the manipulator controller.

Controller Model	OpenCM9.04-B
CPU	STM32F103CB (ARM Cortex-M3)
Operating Voltage	7-16 V (5 V programming only over USB)
External I/O Pins	26
Timers	8
Analog In Pins (ADC)	10 (12 bit)
Flash	128 kB
SRAM	20 kB
Clock Speed	72 MHz
USB 2.0 Full Speed Ports	1
CAN	1
USART	3
SPI	2
I^2C (TWI)	2
Debug	JTAG & SWD
TTL Port (3-Pin)	4
External Sensor Ports (5 Pin)	4
Dimensions	27 x 66.5 mm
Weight	13 g

Connectors:

- The four motors in the mobile base have a D- type connectors which can be plugged-in in only one way. This prevents the problem of reverse polarity. The ESCs have an internal low voltage and high thermal protections. (4 Connectors)
- Kinect has two connectors. One for the 12V 1A power and the other for the data transfer.(2 Connectors)
- The Hokuyo we are using has a single USB 2.0 interface cable. (2 Connectors)
- The scissor lift actuator has a Flat ribbon cable connector for powering the motors and for the control signals. (1 Connector)
- The Arndale single board computer requires one barrel connector for the DC power input. (1 special Connector and multiple pin-pin connectors)
- The Arduino boards require a USB connector and single strand jumper wires for othe various connections. The servos come with a proprietary connectors which can be

directly connected to the female berg type connectors on the Arduino boards.(3 connectors)

- Speaker requires a 3 mm stereo audio jack (1 Connector).
- The manipulator control board has 2 x 20 pin male header row,2 x 20 pin female header row and a USB micro-B connector (5 Connectors)

Power control switches:

Our design has two separate power sources one for the mobile base and the other for the rest of the system. Our robot has a manual override feature which acts as a kill switch for the robot. For this feature we plan to have a mechanical control switch for both of these power supply systems which will control the power to all the other subsystems. Two Single pole Single Throw switches will act as the main control switches for the power supply.

Summary

Since the mobile base already has a well-established power supply system, we have to design a power supply system only for the remaining subsystems. Apart from the Kinect, IMU, scissor lift actuator and the Dynamixel servos, other components can be operated using the USB ports on the single board computer. Since the IMU is capable of operating at the same 12V as required by the other high power drawing components, we can have a common 12V power supply to supply these sensors and actuators. Thus we just have to design a 12 power supply unit with regulation for the power distribution.