Team B - ARCUS
Power Distribution Schematic Analysis

As mentioned in our conceptual design, we have the following output requirements and input capacity:

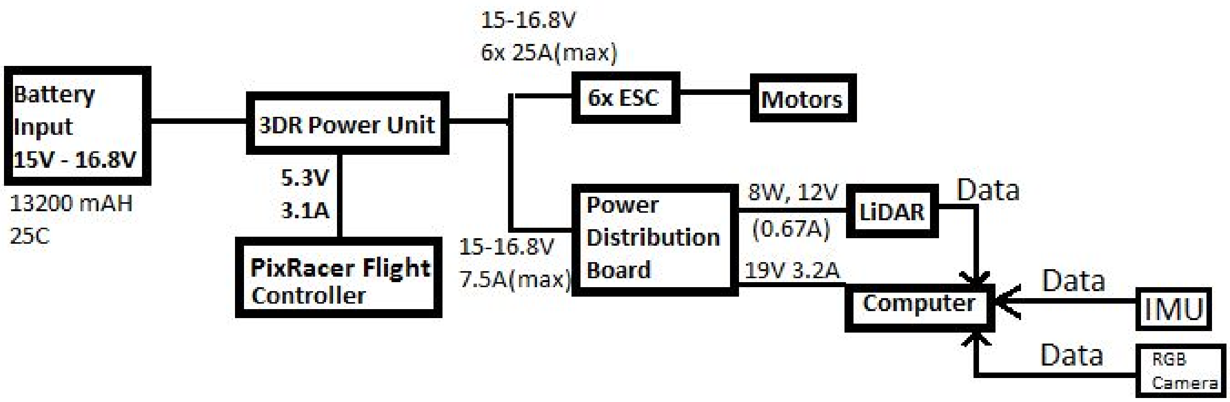

Fig1: Power Distribution Diagram

Outputs:

1. LiDAR: 12V, $\mathbf{P_{LiDAR} = 8W}$ ⇒ 0.67A Nominal Current
2. Gigabyte BRIX On-board Computer: 19V, 3.42A ⇒ $\mathbf{P_{GB} = 65W}$
3. Pixracer: 5.3V, 3.1A ⇒ $\mathbf{P_{PH} = 16.43W, I^{PH}_{in,max} = 3.1A}$
4. Motors, max continuous power ⇒ $\mathbf{P_M = 6*25A*16.8V = 2520W, I^M_{in,max} = 6*25A = 150A}$

Inputs:

4S, 6600mAH, 25C LiPo Batteries

1. Max current possible = $\mathbf{I_{in,max} = 6.6A*2*25 = 330A}$
2. Max power at max voltage (4.2V/cell) = $\mathbf{P_{in,max} = 16.8V*330A = 5544W}$
3. Max power at min voltage (3.2V/cell) = $\mathbf{P_{in,min} = 12.8V*330A = 4224W}$
4. Min input power(3.2V/cell) for PixRacer ⇒ $\mathbf{P^{PH}_{in} = 12.8V*I^{PH}_{in,max} = 12.8V*3.1A = 39.68W}$
5. Max input power(4.2V/cell) for Motors ⇒ $\mathbf{P^M_{in} = 16.8V* I^M_{in,max} = 2520W}$

Regulators:

1. 12V regulator: MIC29150-12BU
    a. **$I^{12V}_{in,max}$ = 0.67A + 2*20mA = 0.71A**
    b. $V_{in,max}$ = 16.8V (nominal, 4.2V/cell)
    (min. required 13V for 12V regulation by regulator)
    c. $P_{out} = P_{LiDAR} + 2*P_{LED}$
    d. P^{12V}_{out} = 8 + 2*(12V*20mA) = 8.24W
    e. **$P^{12V}_{in,max}$ = 16.8V*(0.67A + 2*20mA) = 11.928W**
    f. **Efficiency = 8.24/11.928 = 69%**

2. 19V Step-up regulator: **90% efficiency**
    a. $P_{out} = P_{GB} + 2*P_{LED}$
    b. P^{19V}_{out} = 65W + 3*(19V*20mA) = 66.14W
    c. **⇒ $P^{19V}_{in,max} = P_{out}/(90\%)$ = 73.5W**
    d. For max battery voltage of 16.8V (4.2V/cell) ⇒ 4.37A current draw
    e. For min battery voltage of 12.8V (3.2V/cell) ⇒ 5.74A current draw
    f. **$I^{19V}_{in,max}$ = 5.74A**

Hence, the total requirements and capacities are:

1. $P^{Total}_{out} = P^{12V}_{out} + P^{19V}_{out} + P_{PH} + P_{M} + P^{12V}_{D}$= 8.24+65.76+16.43+2520W = 2610.43W
2. $P^{Total}_{in, required} = P^{12V}_{in} + P^{19V}_{in} + P^{PH}_{in} + P^{M}_{in}$ = 11.928+73+39.68+2520 = 2644.61W
3. Battery capacity = $P_{in,min}$= 4224W
4. $I^{Total}_{in, required} = I^{12V}_{in,max} + I^{19V}_{in,max} + I^{PH}_{in,max} + I^{M}_{in,max}$ = 0.71+5.71+3.1+150 = 159.52A
5. Max battery current = $I_{in,max}$ = 330A

Hence, our circuit meets the battery capacity and output requirements.

The schematic however, contains the circuit without the PixRacer, and the ESCs. As they won't be attached to the power board.

Schematic

The schematic, therefore is the contents of the last box of Fig 1.
Mainly the power distribution for LiDAR and the Computer (Gigabyte BRIX).
The circuit uses 7 LEDs to indicate:

1. Battery Connection
2. Adapter connection to the Gigabyte BRIX
3. 12V output from regulator to LiDAR before the fuse
4. 12V output from regulator to LiDAR after the fuse
5. 19V output from regulator to PowerPath Controller
6. 19V output from PowerPath Controller to Gigabyte BRIX before the fuse
7. 19V output from PowerPath Controller to Gigabyte BRIX after the fuse

1. **LiDAR Circuit**

The LiDAR Circuit employs a MIC29150-12BU which has protection against overcurrent faults, reversed input polarity, reversed lead insertion, overtemperature operation, and positive and negative transient voltage spikes.

The 12BU package is for a regulated output of 12V and comes in a TO-263 package. It can handle currents up to 1.5A. Given our requirement of $\mathbf{I^{12V}_{in,max} = 0.71A}$, this chip works well.

Thermal consideration:

P^{12V}_{D} = Thermal Power dissipation from datasheet

$P^{12V}_{D} = \mathbf{I^{12V}_{in,max}*(1.01*}V_{in,max} - V_{out}\mathbf{) = 0.71*(1.01*16.8 - 12) = 3.53W}$

Next, calculate the junction temperature for the expected power dissipation.

Considering max ambient temperature (T_A) = 30°C

$T_J = (\theta_{JA} \times P_D) + T_A = (56°C/W \times 3.53W) + 30°C = 227.68°C$

Now determine the maximum power dissipation allowed

that would not exceed the IC's maximum junction temperature (125°C) without the use of a heat sink by :

$P_{D(MAX)} = (T_{J(MAX)} - T_A)/\theta_{JA} = (125°C - 50°C)/(56°C/W) = 1.34W$

Then the heat sink thermal resistance is determined with:

$\theta_{SA} = ((T_{JMAX} - T_A)/P_D) - (\theta_{JC} + \theta_{CA})$

TO-263 (θ_{JC}) = 2°C/W

Heatsink required for 12V regulator

$\mathbf{\theta_{SA} = ((125 - 30)/3.53W) - (2 + 0) = 24.91°C/W}$

2. Gigabyte BRIX circuit

For the DC 12V(9-18V) to 19V step-up DC/DC converter,

Working temperature: (-40°C~ 85°C)

Full load temperature rise: 50°C

Ambient temperature: 30°C

Final device temperature 80°C

Hence, a heat sink may be required depending on experimental observation

3. Power Path Management

The power path management is implemented for the Gigabyte BRIX power.

When an adapter is present, the power from the 19V DC/DC converter is switched off by the PMOS power transistor (NTMD6P02). In the absence of an adapter, the 19V DC/DC output is used to power the Gigabyte BRIX.

An off-the-shelf IC (LTC4412 - Low Loss PowerPath Controller in ThinSOT) is used to enable the power management.

The IC works for 3V to 28V AC/DC Adapter Voltage Range and 2.5V to 28V Battery Voltage Range

The application circuit is followed according to the datasheet

The voltage at STAT pin can be measured to check if an auxiliary input is connected. (It will be pulled LOW in case our adapter is connected).
The PMOS is selected to work such that the GATE can be pulled up to the SENSE Voltage (19V).
The selected PMOS (ON Semiconductor NTMD6P02R2G) is rated to work at 20V with 6A Drain current. Since our system requirement is 3.42A (for BRIX) + 3*20mA(for 3 LEDs) = 3.48A, the PMOS meets our requirements.
Thermal effects may require heatsink on the PMOS too