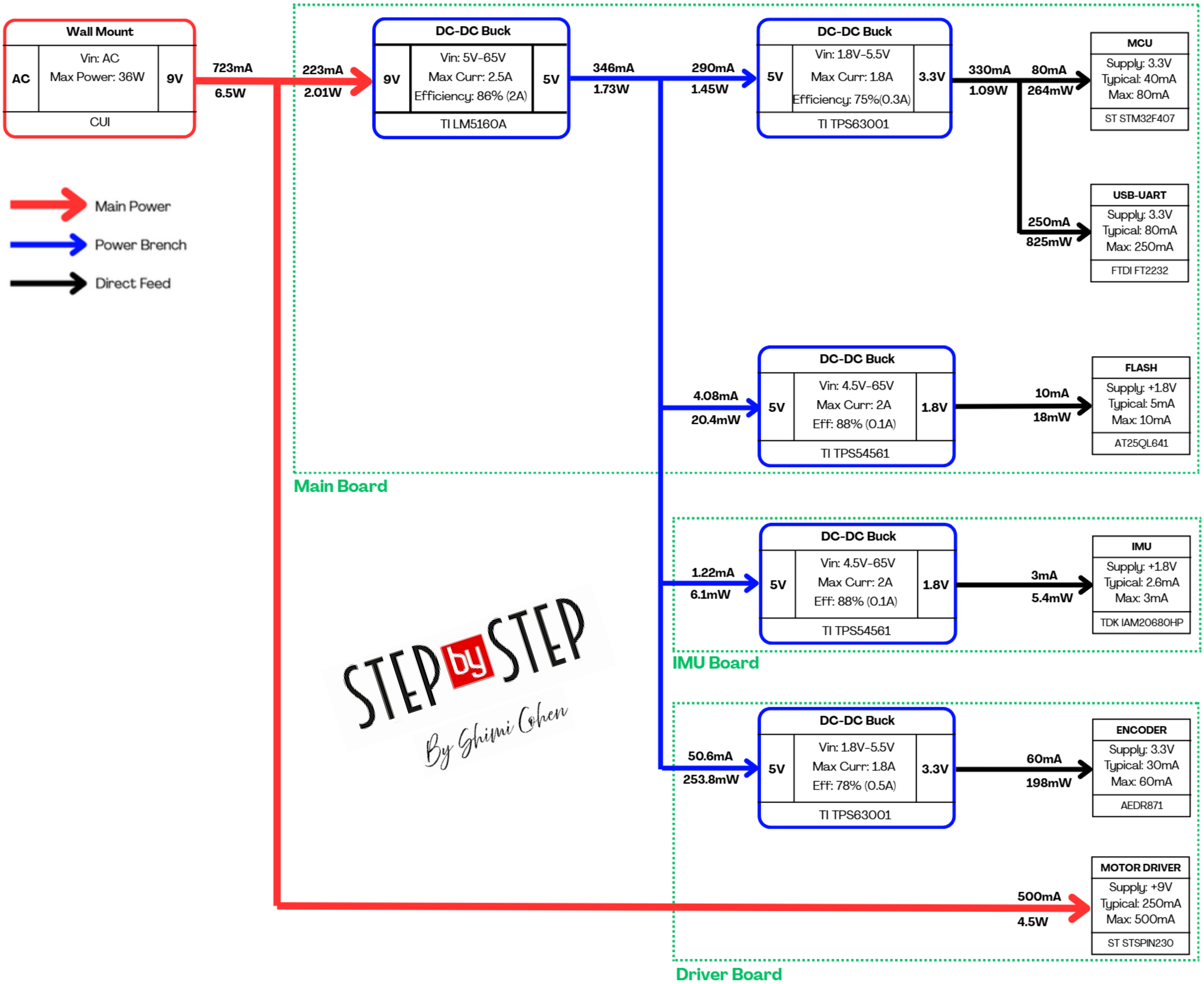
Master Your

POWER TREE



INTRODUCTION

Power tree diagrams serve as the foundation for successful embedded system design. They provide visual clarity for complex power distribution networks and ensure proper power budgeting from project inception. Modern embedded systems demand multiple voltage rails, efficient power conversion, and reliable operation across varying load conditions.

A well-constructed power tree diagram eliminates guesswork and prevents costly design iterations.

Why Power Trees Matter:

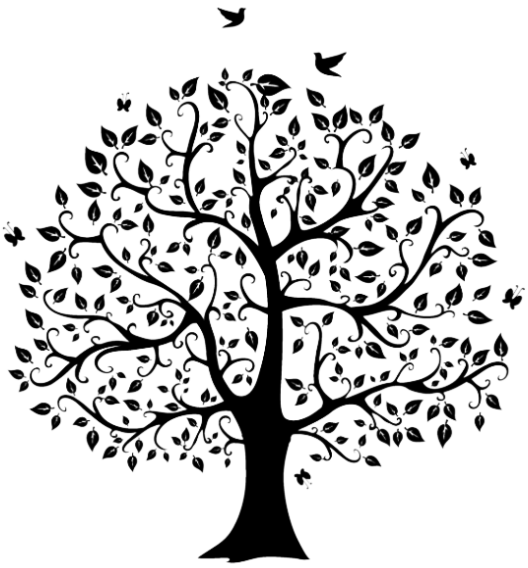
Power tree diagrams solve critical design challenges:

- **Prevent power budget errors** that lead to system instability
- **Identify efficiency bottlenecks** before hardware implementation
- **Communicate power requirements** clearly across engineering teams
- **Enable accurate component selection** for power supplies and regulators
- **Facilitate thermal analysis** and heat dissipation planning

Overview:

Power trees are essential during these design phases:

Design Phase	Power Tree Application
Concept	Initial power estimation and feasibility
Architecture	Rail count determination and topology
Detailed Design	Component selection and optimization
Validation	Power budget verification and testing
Production	Manufacturing guidelines and troubleshooting



STEP 1: SCOPE

Proper scope definition ensures your power tree captures all necessary information without unnecessary complexity. Clear boundaries prevent confusion and maintain diagram usefulness.

1.1 WHAT BELONGS IN A POWER TREE

Include these essential elements:

- Primary power inputs (battery, USB, wall adapter, PoE)
- Power conversion stages (switchers, LDOs, charge pumps)
- Every powered load (MCU, sensors, active components)
- Power branches between supplies
- Current & voltage specifications for each P.S & load

Exclude these items to maintain clarity:

- Signal routing information (belongs in system diagrams)
- Detailed component specifications (belongs in schematics)
- Physical connector pinouts (belongs in interface documents)

1.2 REQUIRED PARAMETERS

Document voltage parameters with precision:

Parameter Type	Specification Format	Example
Main Supply Power	Max Power: Power (W)	Max Power: 120W
P.S Input Range	Min - Max	5V - 45V
P.S Output Voltage	Nominal Out	3.3V
P.S Efficiency	Efficiency @ Current	88% @ 2A
P.S Max Current	Max Current (A)	5A Max
Load Voltage Supply	Supply: Voltage (V)	Supply: 3.3V
Typical Load Consumption	Typical: Current	Typical: 100mA
Max Load Consumption	Max: Current	Max: 250mA

1.3 POWER SUPPLIES & LOADS

Classify power supplies by function and characteristics:

Primary Supplies:

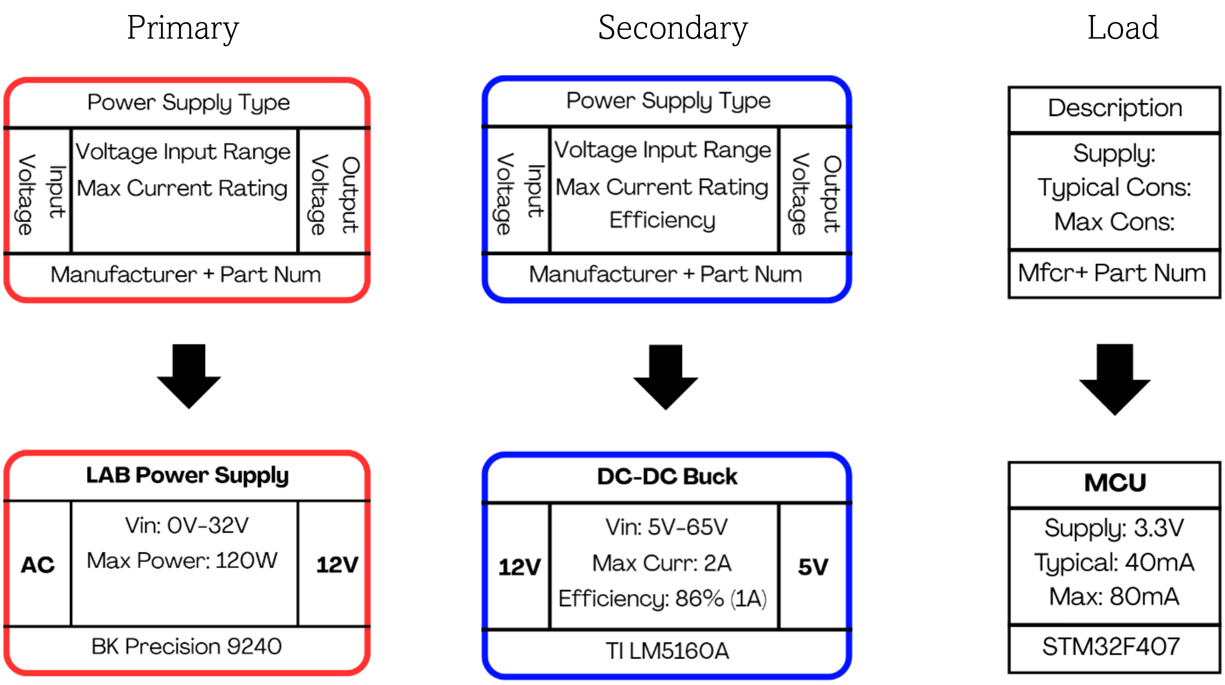
- Main system power (In Red)
- Battery Supply (In Red)

Secondary Supplies:

- Derived from primary supplies
- Switching Regulators
- Low Dropout Output
- Charge Pumps

Loads:

- Continuous loads: MCU core, oscillators, always-on circuits
- Intermittent loads: communication modules, sensors during acquisition
- Peak loads: motor drives, transmitters, flash programming



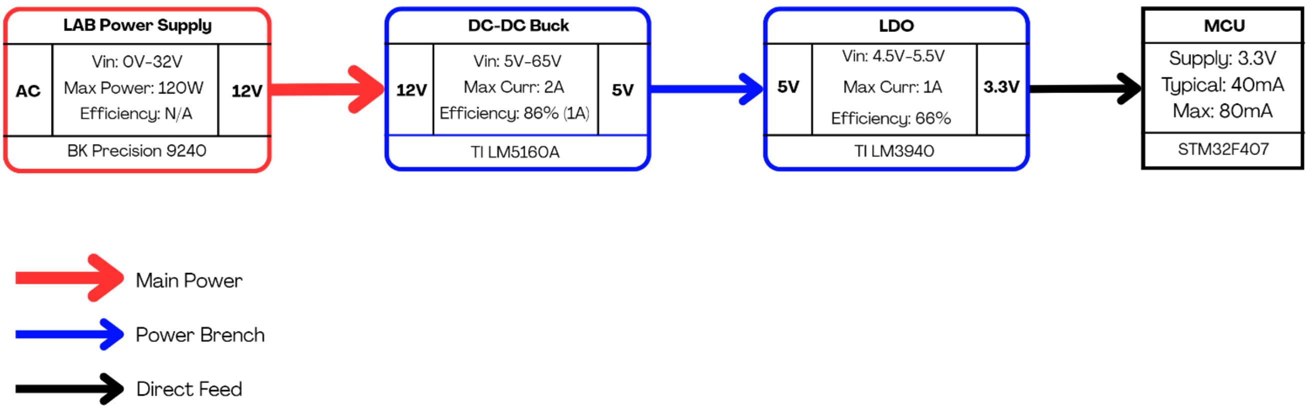
STEP 2: SYMBOLS

Consistent symbology and clear visual hierarchy create professional, readable power tree diagrams. Standardized elements enable quick comprehension by any engineer reviewing the design.

2.1 ARROWS

Arrow conventions establish clear power flow direction:

- **Red Thick arrows** indicate main power supply
- **Blue Medium arrows** indicate secondary power supply
- **Black Thin arrows** represent direct feed to load
- **Arrow direction** always flows from supply to load

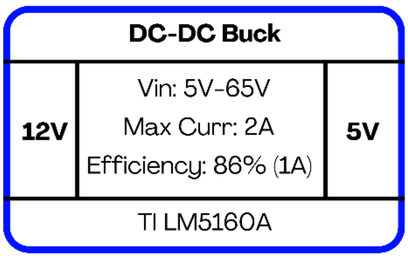


2.2 POWER SUPPLIES AND LOADS

Use consistent symbols throughout your designs:

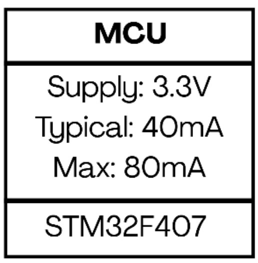
Rectangle for Power Supply Symbols:

- Tag the main Power Supply
- Tag "BATT" label for Battery Supply
- Tag "LDO" for linear regulators
- Tag "DC-DC" and type for switching regulators



Square for Load Symbols:

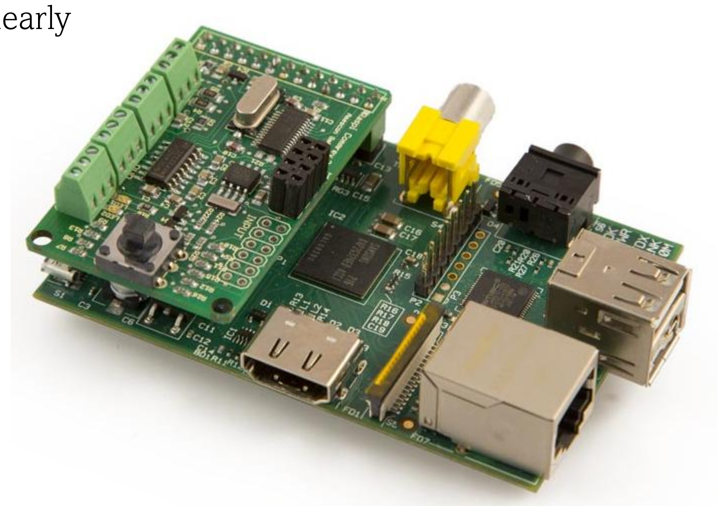
- Simple square for all loads
- Specify the consumption (Vs. Current)
- Tag Loads that require multiple rails



2.3 BOARD SEPARATION AND MULTI-PCB

Multi-board systems require clear boundary indication:

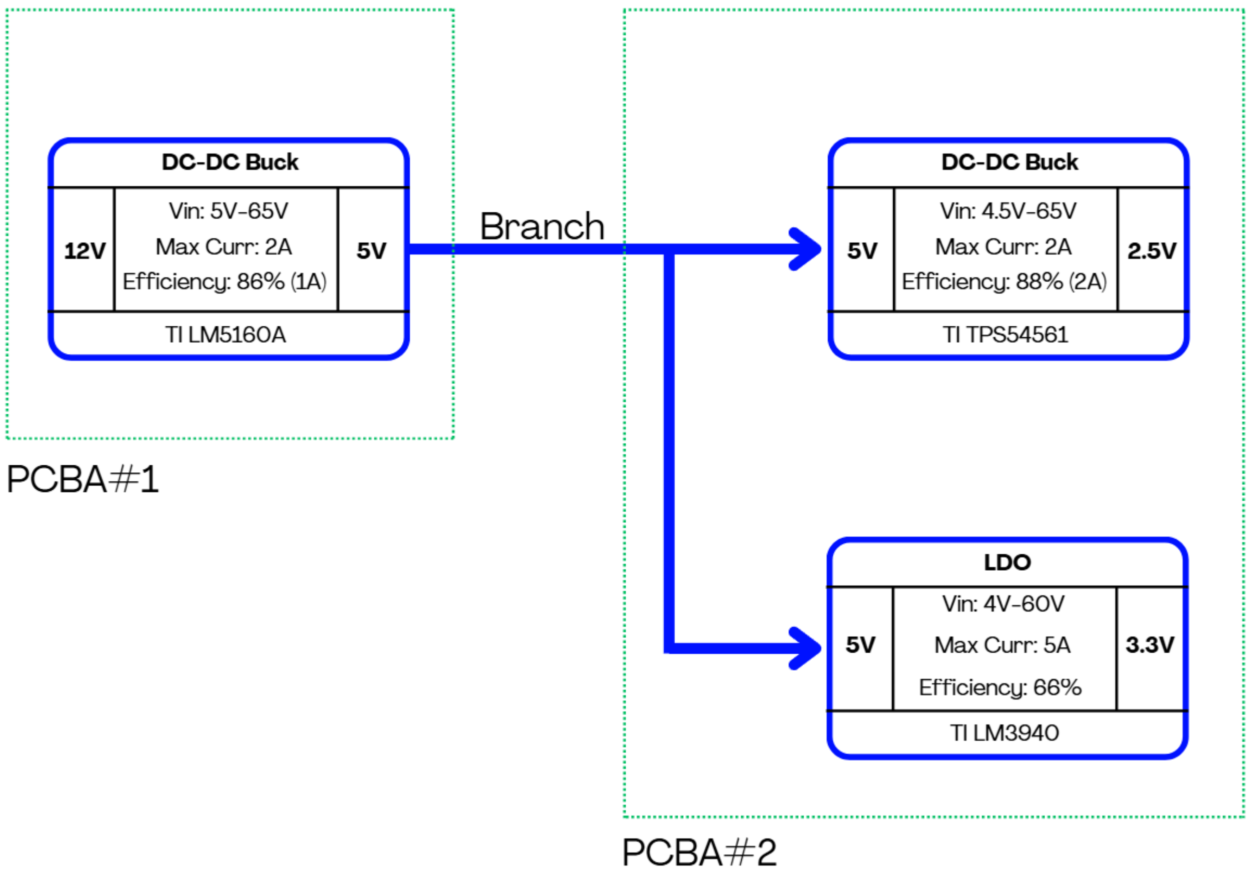
- **Dashed vertical lines** separate different PCBAs
- Use Green Dashes Reminding PCB
- **Board labels** identify each PCB clearly



2.4 POWER BRANCHES

When One P.S feeds multiple Power Supplies use branches.

- **Blue arrows** represent branch
- **Branches connect** between Providing P.S to Consuming P.S
- **Sum the Consuming P.S** power to get total from Proving P.S

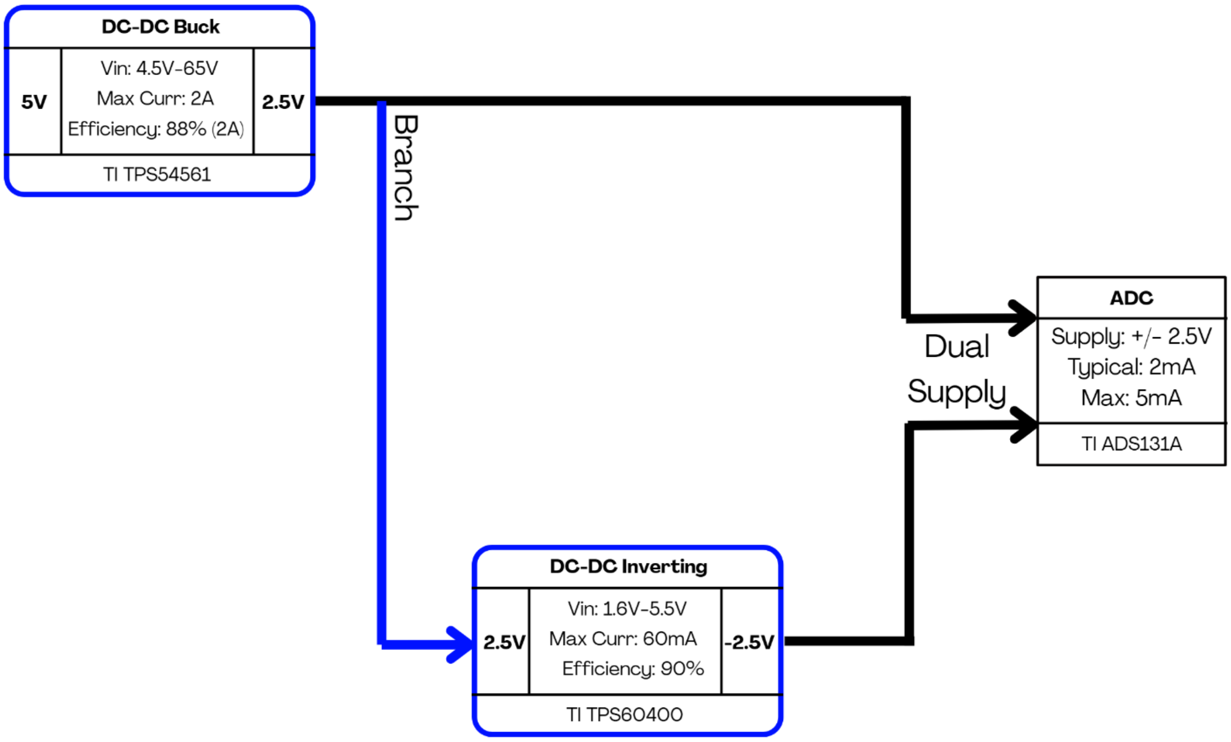


2.5 MULTIPLE SUPPLY LOADS

Some loads more than one supply.

The following ADC requires dual supplies. Both generated from the same source, which is why the branch is needed here.

- Black arrows represent direct feed
- Connect all supplies to the Load
- Each Rail will be calculated backwards separately



The Source Power will be calculated as followed:

Required_Power = ADC_Power + Inverting_Power (w/ efficiency)

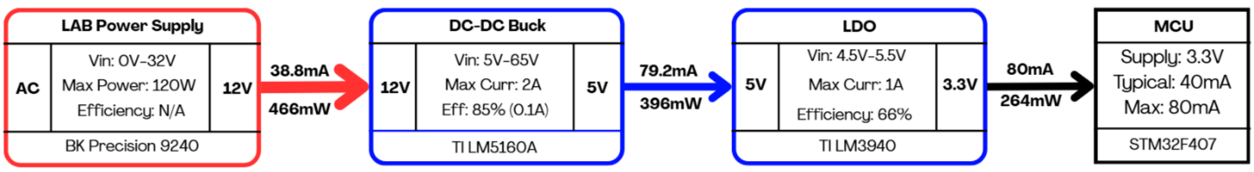
RP = 12.5mW + (150mW / 0.9) = **179mW**

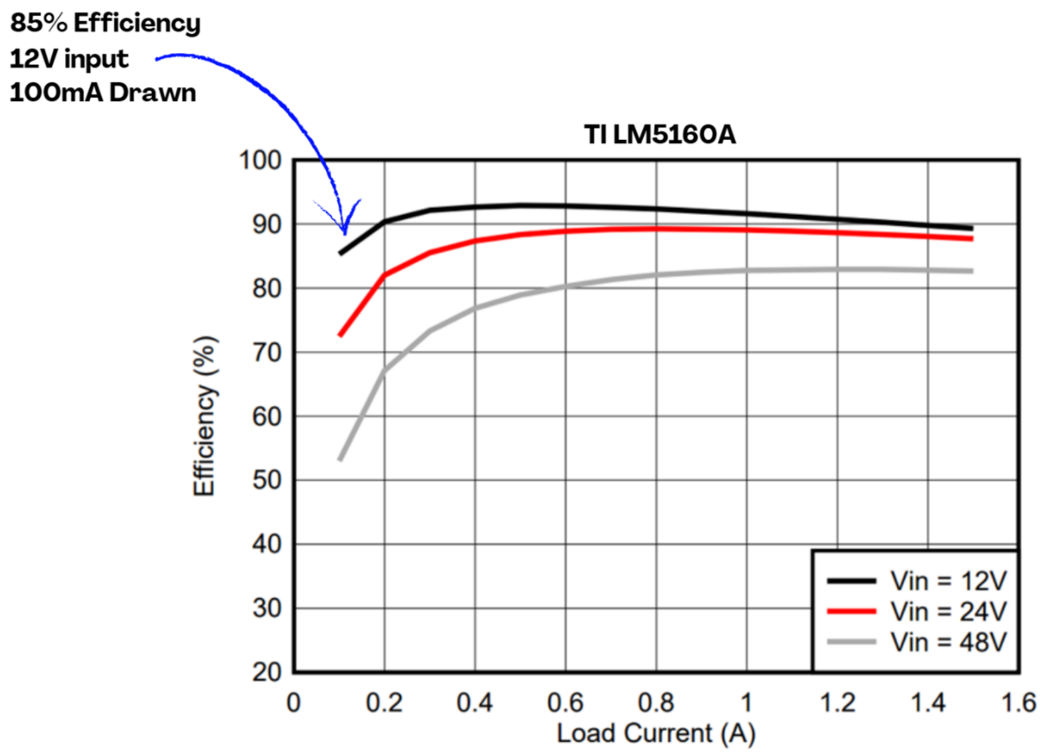
2.6 CURRENT AND POWER PRESENTATION

Current and power should be presented as followed:

- Current above the arrow and power below it
- Present power and current for Each P.S output
- Present power and current For Each Load Feed
- Present power and current For Each P.S Input in case of a branch
- Avoid duplicate data presentation
- Efficiency relies on the drawn current check Datasheet for accuracy
- Always calculate efficiency according to your application

Below case shows that to drive MCU that consumes 264mW, main P.S must provide 466mW because of the cascaded efficiencies





STEP 3: DATA GATHERING

Accurate data collection forms the foundation of reliable power tree analysis. Systematic documentation prevents errors and enables design verification throughout the development process.

3.1 COMPLETE LOAD INVENTORY

Create comprehensive load table

Data Accuracy

- Check Datasheet of each load
- Make sure you cover max and typical cases
- In case of intermittent loads use average current
- Some loads are Voltage sensitive (tolerance) make sure they handled properly
- Choose the P.S that right for your load (LDO for low current low ripple load etc.)

3.2 LOAD SPEC TABLE

Document specifications in standardized format:

Component	Supply [V]	Typical I[mA]	Max I[mA]
IMU	1.8	2.6	3
MCU	3.3	50	80
WiFi Module	3.3	80	250
Sensor	3.3	2	5
ADC	+/-2.5	60	100

Note: Current are presented as average in case of intermittent loads

Typical Operating Circuit of section 4.2, VDD = 1.8V, VDDIO = 1.8V, T_A = 25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SUPPLY VOLTAGES						
VDD		1.71	1.8	3.6	V	1
VDDIO		1.71	1.8	3.6	V	1
SUPPLY CURRENTS & BOOT TIME						
Normal Mode	6-axis Gyroscope + Accelerometer		3		mA	1
	3-axis Gyroscope		2.6		mA	1
	3-axis Accelerometer, 4 kHz ODR		390		µA	1
Full-Chip Sleep Mode			6		µA	1
TEMPERATURE RANGE						
Specified Temperature Range	Performance parameters are not applicable beyond Specified Temperature Range	-40		+105	°C	1, 2

3.3 COMPLETE POWER SUPPLY INVENTORY

Create comprehensive load table

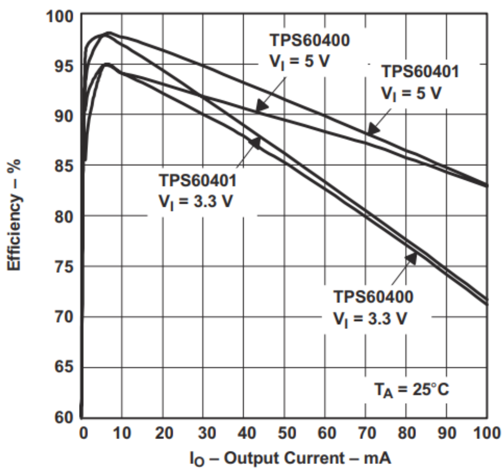
Data Accuracy

- Check Datasheet of each Power Supply
- Efficiency is a function of Vin, Current and even Switching frequency
- Use the proper tables in Datasheet to determine to proper efficiency
- Pay attention to Max current / Power rating
- Find Input Range in datasheet

3.4 POWER SUPPLIES SPEC TABLE

Each Power supply will be filled in this table:

Component	In Range [V]	Input [V]	Output [V]	Efficiency	Max [A]
Buck TPS54561	4.5 - 60	12	5	88%	2A
Inverter TPS60400	1.6 - 5.5	2.5	-2.5	70%	60mA
LDO LM3940	1.8 - 5.5	5	3.3	66%	5A
Main Power	N/A	N/A	12	N/A	4A (48W)



7.3 Recommended Operating Conditions

	MIN	NOM	MAX	UNIT
Input voltage range, V_I	1.8		5.25	V
Output current range at OUT, I_O			60	mA
Input capacitor, C_I	0	$C_{(fly)}$		µF
Flying capacitor, $C_{(fly)}$		1		µF
Output capacitor, C_O		1	100	µF
Operating junction temperature, T_J	-40		125	°C

STEP 4: POWER CALCULATIONS

Accurate power calculations ensure adequate supply sizing and prevent system failures. Systematic analysis methods catch errors before hardware implementation and enable design optimization.

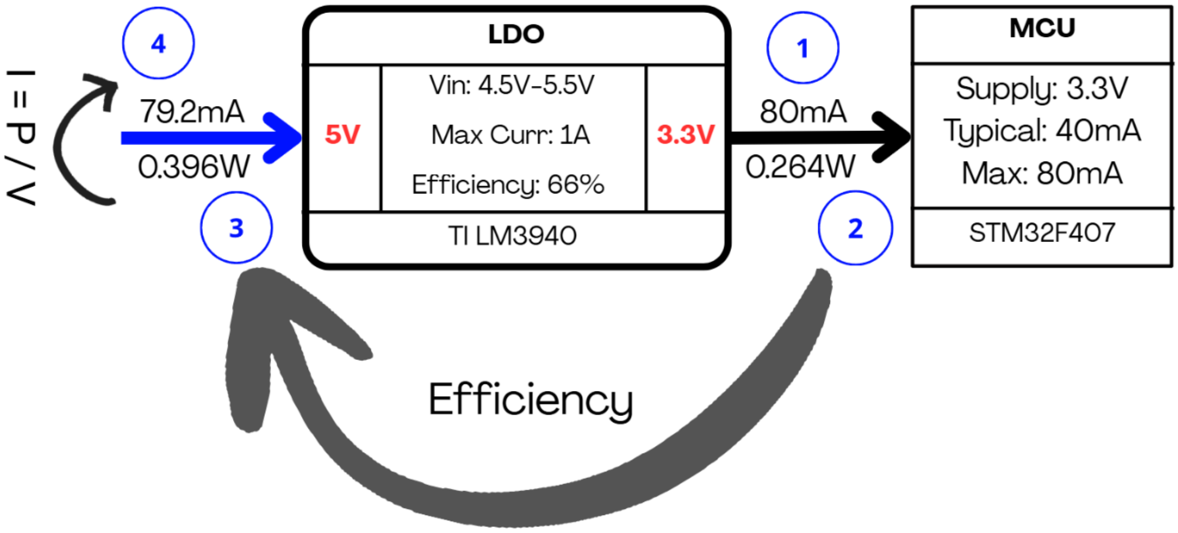
4.1 EFFICIENCY CALCULATION

Efficiency directly impacts:

- Battery life in portable applications
- Heat generation and thermal management requirements
- Input power specifications for wall adapters and USB supplies

Calculate total input power:

- Always start from Loads and go back to supplies.
- Check the Datasheet for load consumption and P.S Efficiency
- $Input\ Power\ =\ Output\ Power\ \div\ Efficiency$



1. Max Load Current By Data sheet : **80mA**
2. Load Power = Current x Voltage = 80mA x 3.3V = **0.264W**
3. Required power = Out Power / Efficiency = 0.264W / 0.66 = **0.396W**
4. Input Current = Req. Power / Input Voltage = 0.369W / 5 = **79.2mA**

Note: In & out currents are almost identical, but the In & out power aren't (efficiency)

4.2 LOAD CURRENT SUMMATION

Calculate currents using appropriate summation techniques:

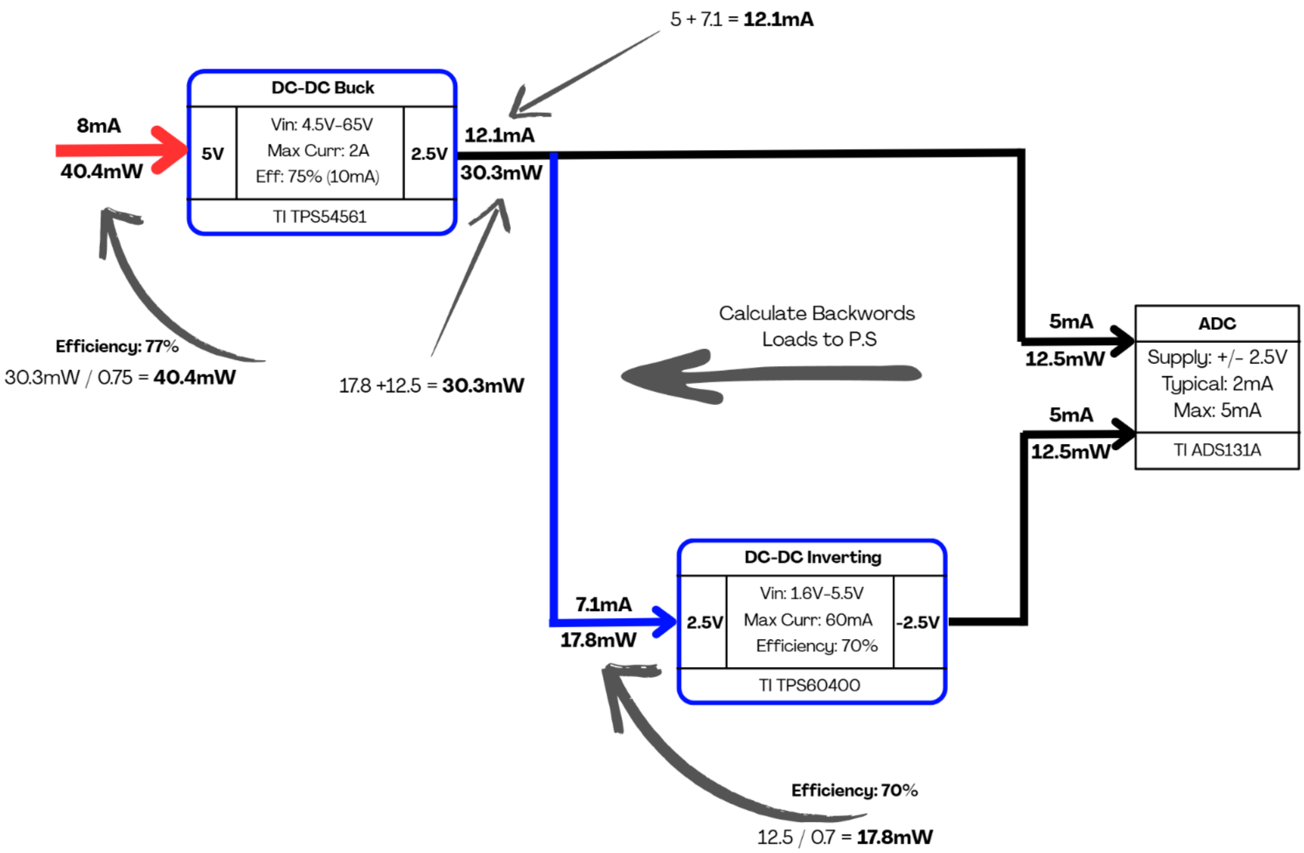
Simultaneous Loads:

- Add all currents directly
- Use maximum current specifications
- Pay attention to startup current spikes

Non-Simultaneous Loads:

- Calculate worst-case combination
- Consider operational modes
- Account for sequencing requirements

Example Calculation:



STEP 5: POWER TREE EXAMPLE

Building clear, professional power tree diagrams requires systematic approach and attention to visual hierarchy. Proper construction techniques ensure diagrams remain readable and useful.

5.1 ESSENTIAL STEPS

Step-By-Step

1. Gather the system power requirements (all loads)
2. Address each load with the proper rails (select P.S)
3. Gather a table of Loads and Power Supplies (include relevant parameters)
4. Calculate from loads backwards once you have initial tree layout
5. Optimize the tree based on calculation (e.g. Supply hit max current rating)
6. Now verify power tree calculation going forward, from P.S to loads

5.2 PROJECT DESCRIPTION

Linear Motion Control

PCBA1 - Interface Board:

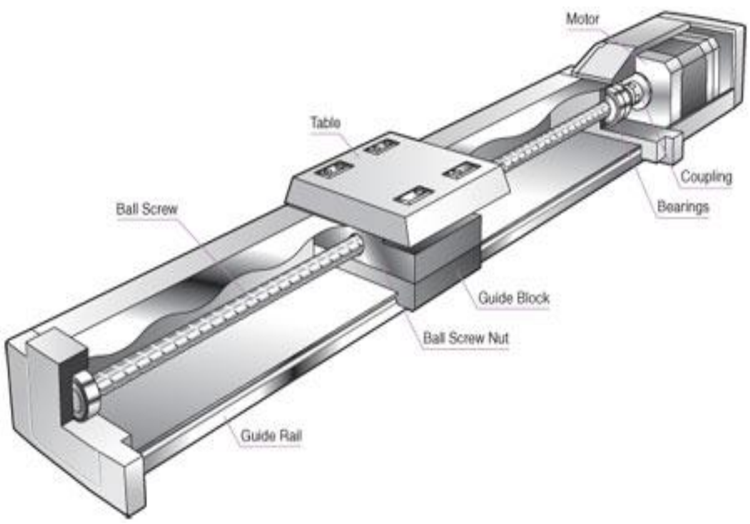
- Main power input 12V
- STM32F4 MCU
- UART-to-USB converter
- Flash Memory

PCBA2 - Motor Driver Board:

- Powered from Main
- 3 Half-Bridges for Motor
- Optic Encoder

PCBA3 - IMU Board:

- Powered from Interface Board
- 6DOF IMU



Note: MCU, Encoder, Flash and IMU require their own Power Supply (Noise)

5.3 GATHER ALL SPEC

Load SPEC

Component	Supply [V]	Typical I[mA]	Max I[mA]	PCBA
IMU IAM-20680HP	1.8	2.6	3	3
MCU STM32F407	3.3	40	80	1
USB-UART FT2232H	3.3	80	250	1
Flash AT25QL641	1.8	5	10	1
Driver STSPIN230	9	500	1000	2
Encoder AEDR871	3.3	30	60	2

Power Supply SPEC

Component	In Range [V]	Input [V]	Output [V]	Efficiency	Max Current
Buck TPS54561	4.5 - 60	5	1.8	81%(0.1A)	2A
Buck LM5160A	5 - 65	12	5	88%(1A)	60mA
Buck TPS63001	1.8 – 5.5	5	3.3	78%(0.5A)	1.8A
Main Power	N/A	N/A	12	N/A	3A

Interface Board(1):

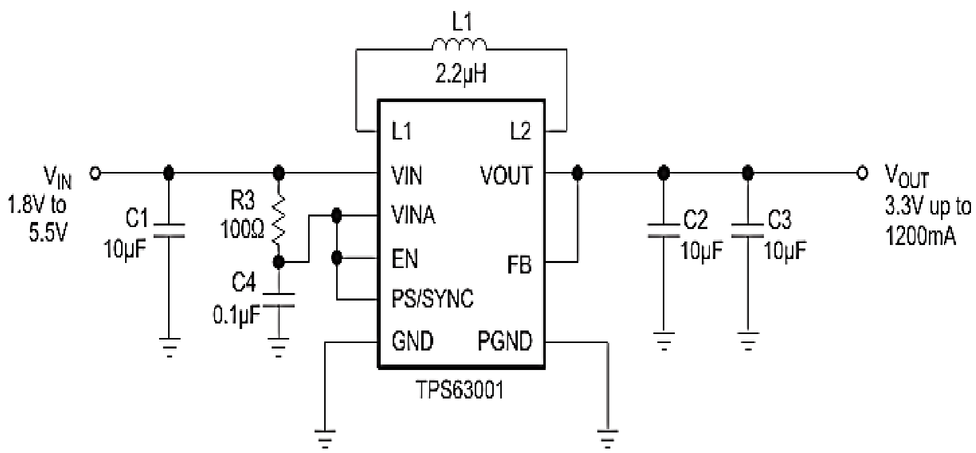
- Buck LM5160A (Powered my Main) – 5V Output
- Buck TPS54561 (Powered by LM5160A) – 1.8V Output
- LDO LM3940 (Powered By LM516A) - 3.3V Output

Motor Driver Board(2):

- Buck TPS63001 (Powered By LM5160A) - 3.3V Output

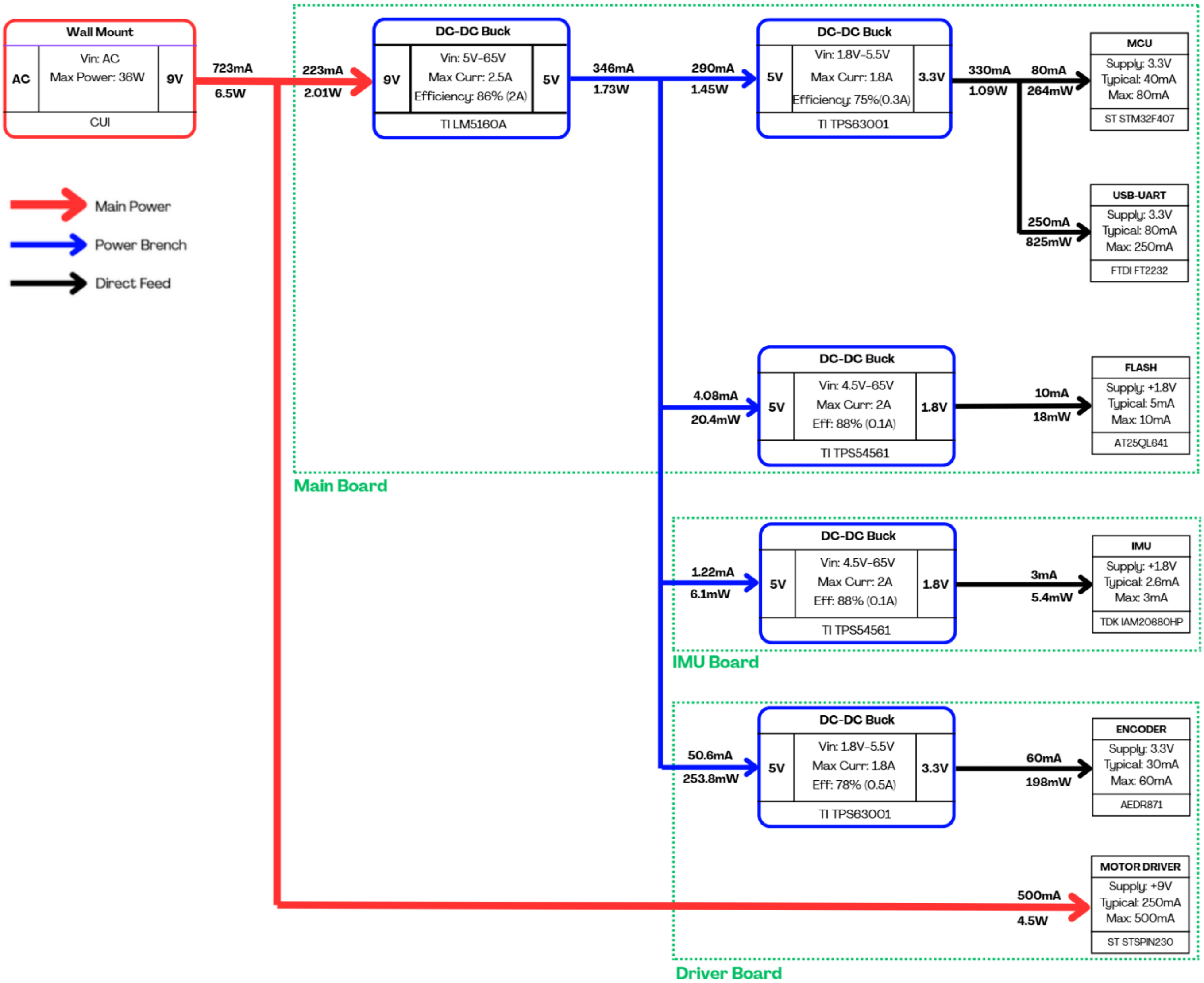
IMU Board(3):

- Buck TPS54561 (Powered by LM5160A) – 1.8V Output



5.4 POWER TREE DIAGRAM

After collecting, calculating and planning its time to draw our tree:



Total Efficiency:

1. Summarize all consumption :

ToT_Cons = 264mW+825mW+18mW+5.4mW+198mW+4.5W= 5.8W

2. Find the total consumption from the Main P.S:

Tot_Power = 6.5W

3. Divide Out / in to get the efficiency:

Efficiency = Tot_Cons / Tot_Power = 89.3%

Note: The reason the efficiency is high is because of the direct feed of 4.5W to the motor driver

STEP 6: TREE VALIDATION

After Drawing the tree it's time to validate it.

6.1 VALIDATE RATING & DATA

Check Each Power Supply:

- Check the Current Output of primary Power Supply
- Check the current output of all secondary supplies
- The output must not exceed 75% of the max current

Tree Structure

- Check each primary branch
- Check each secondary branch
- Validate the distribution of Load & P.S in PCBAs
- Validate branch location (outside or inside PCBA)

Data Validation:

- Check the Loads SPEC list (attach to tree)
- Check the P.S SPEC list (attach to tree)

6.2 VALIDATE BRANCHES

First Branch(Main):

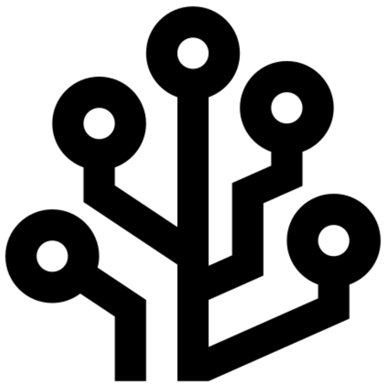
723mA = 223mA + 500mA

6.5W = 2W +4.5W

Second Branch(LM5160A):

346mA = 290mA+4.08mA+1.22mA+ 50.6mA

1.73W = 1450mA+20.4mA+6.1mA+253.8mA



Third Branch(TPS63001):

330mA=80mA+250mA

1090mW = 264mW+825mW

6.3 VALIDATE SUPPLY EFFICIENCIES

TPS63001(feeding MCU & Converter)

1.45W = 1.09W / 0.75

TPS54561(feeding Flash)

20.4mW = 18mW / 0.88

TPS54561(feeding IMU)

6.1mW = 5.4mW / 0.88

TPS63001(feeding Encoder)

253.8mW = 198mW / 0.78

LM5160A(feeding All)

2W = 1.73W / 0.86

- 6.4 POWER DESIGN Considerations
- Use LDOs where very low noise is required.
- Higher Efficiency is achieved in High outputs in switching regulators
- Minimum P.S types increases DFM
- Pay attention to Loads requiring low ripple supply
- Variable Power input sometimes forces Buck-Boost Regulators
- Boost operation is usually less efficient than buck
- Some Loads may demand their own rails (AVDD etc.)
- Avoid working too close to supply max rating

CONCLUSION

Power tree diagrams serve as critical communication tools throughout the product development lifecycle. Effective power tree design requires systematic approach, attention to detail, and comprehensive validation. The methods presented in this guide provide reliable framework for creating professional, accurate power distribution diagrams.

The step-by-step methods outlined here scale from simple single-board designs to complex multi-board systems.

Key success factors include:

- Thorough planning and scope definition before diagram creation
- Accurate data collection and systematic documentation practices
- Professional presentation standards that enhance clarity and usability
- Comprehensive validation processes that catch errors early
- Optimize the Design Use the tree to find weak spots (low efficiency etc.)