(B) ELECTRONICS SPECIFICATION

a. COMPONENTS

1. **Servos – 20 kg·cm × 18**

   High-torque digital servos, each rated at **20 kg·cm torque @ 7.4 V** with a speed of **0.14 s/60°**. Provide strong, stable, and precise actuation across 18 joints, enabling the robot to climb stairs, traverse rubble, and carry its own weight.

2. **Raspberry Pi 4 -** Quad-core ARM Cortex-A72 processor at 1.5 GHz, with 4 GB RAM and integrated Wi-Fi/Bluetooth. Serves as the high-level computer for SLAM, AI decision-making, sensor fusion, video streaming, and mission planning.

3. **Teensy 4.1 -** High-performance ARM Cortex-M7 microcontroller running at 600 MHz, supporting 35 PWM channels and multiple UART/I²C/SPI buses. Handles real-time servo control and sensor response, ensuring smooth gait execution.

4. **Batteries -** Primary power source: two 16.8 V (4S) 5200 mAh Li-ion pack with a discharge rate of 20C, delivering up to 30-45 minutes runtime in the field under mixed load conditions.

5. **Buck Converter -** High-efficiency DC-DC regulator, input 7–30 V, output 5 V/6 V up to 10 A. Ensures stable power delivery to controllers, sensors, and communication modules.

6. **IR Camera -** Thermal imaging sensor (e.g., FLIR Lepton or MLX90640) with resolution up to 80×60 pixels and temperature range –40 °C to +300 °C. Detects human heat signatures through darkness, smoke, and debris

7. **Human Radar Sensor -** Microwave Doppler radar module with detection range up to 7 m. Capable of sensing motion and presence through light walls or obstructions, enhancing victim localization in low visibility.

8. **USB Camera -** HD video camera with 1080p resolution @ 30 fps and 120° field of view. Provides real-time visual feedback to operators for mapping and victim confirmation.

9. **Microphone -** Omni-directional audio input, sensitivity **–42 dBV**, frequency response **20 Hz–20 kHz**. Captures environmental sounds such as cries, tapping, or movement.

10. **Speaker -** 8-ohm, **3–5 W audio module**, enabling **two-way communication** with victims or broadcasting alarms and rescue instructions.

11. **LiDAR -** RPLidar-class sensor with **12 m range**, **360° field of view**, and scan frequency **5–10 Hz**. Generates detailed 2D maps for **SLAM and obstacle detection** in disaster zones.

12. **Ultrasonic Sensors – HC-SR04 (×6)**
    Short-range distance sensors with range **2–400 cm** and accuracy **±3 mm**. Used for close obstacle detection, edge sensing, and navigation in tight spaces.

13. **LED Strips -** High-intensity white LEDs, **12 V, 5 W** each, luminous flux up to **1000 lm**. Illuminate dark areas and act as **rescue signal indicators**.

14. **GPS Module – NEO-6M**
    Satellite receiver with position accuracy **2.5 m**, baud rate **9600**, and operating voltage **3.3–5 V**. Provides outdoor localization and mission tracking.

15. **Gas Sensor – MQ-2/MQ-135**
    Sensitive to **CO, methane, LPG, and smoke** in the range of **200–10 000 ppm**. Monitors air quality to detect hazardous or unsafe environments.

16. **Temperature & Humidity Sensor – DHT22**
    Measures temperature from **–40 °C to +80 °C (±0.5 °C)** and humidity from **0–100 %RH (±2 %)**. Provides environmental monitoring for fire, flooding, or heat risks.

17. **NRF24L01 Transceiver -** 2.4 GHz wireless communication module, range up to **100 m LOS**, data rate **250 kbps–2 Mbps**, 3.3 V operation. Acts as a **backup telemetry link** to Wi-Fi/LoRa.

18. **Cooling Fan / Heat Sink -** 5 V DC brushless fans (30–40 mm, ~3–5 CFM airflow) paired with aluminum heat sinks. Maintain safe operating temperatures for

Raspberry Pi and Teensy during prolonged high-load processing.

19. **Custom Buck Converter (16V to 5V) -** A custom DC-DC buck converter circuit to step down the robot's input voltage from 16V to a stable 5V for microcontrollers and sensors. This efficient switching design provides reliable low-voltage power while minimizing heat and energy loss, optimizing for safety and performance in challenging field conditions.

20. **ICM-20948 IMU module -** This module integrates a 3-axis gyroscope, accelerometer, and magnetometer to provide accurate orientation and magnetic field data. It enables robust motion tracking and heading estimation, essential for the hexapod's stability and navigation. Its low power consumption and high update rate suit real-time robotic applications.

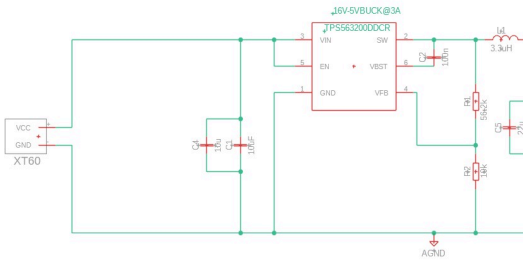

Fig.16a: Custom Buck Converter (16V to 5V) Schematic

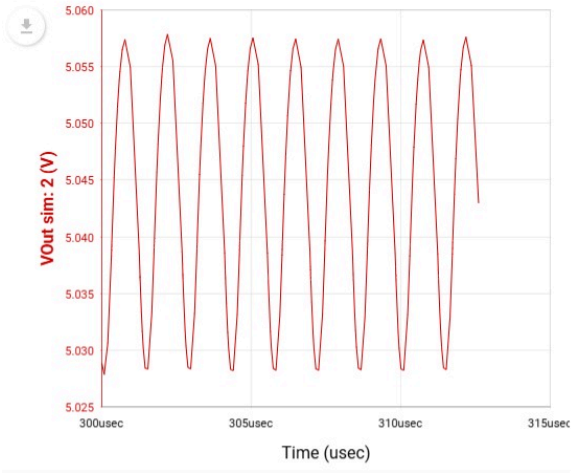

Fig.16b: Buck Converter Simulation

b. POWER CONSUMPTION ANALYSIS

The total estimated peak power draw for the system is **~350.58 Watts**.

Detailed Power Breakdown:

- **Actuation (Servo Motors):** 2.5A × 5V × 18 = **225.0 W**
- **Computing & Control:**
  - Raspberry Pi 4: **~5.0 W**
  - Teensy 4.1: **0.3 W**
- **Sensing & Perception:**
  - IR Camera: **2.0 W**
  - 24GHz Radar: **0.6 W**
  - USB Camera: **3.6 W**
  - LIDAR Sensor: **2.0 W**

    - Ultrasonic Sensor: **0.075 W**
    - GPS Module: **0.1 W**
    - Gas Sensor: **0.3 W**
    - Temperature/Humidity Sensor: **0.0005 W**
- **Audio & Communication:**
    - Microphone: **0.15 W**
    - Speaker: **~1.0 W** (Estimated, not explicitly stated)
- **Illumination:**
    - LED Strips: **10.0 W**
- **Thermal Management:**
    - Cooling Fan/Heatsink: **~2.0 W** (Estimated for a small fan)

Battery Life Estimation

Using **4S 16.8V, 5200mAh (5.2Ah)** LiPo battery:

1. **Total Current Draw:** I = P / V = 350.58W / 16.8V ≈ 20.86A
2. **Theoretical Runtime:** Capacity / Draw = 5.2Ah / 20.86A ≈ 0.249 hours
3. **Runtime in Minutes:** 0.249 hrs × 60 ≈ 14.95 minutes

Conclusion: Under full load (all servos moving and all systems active), the estimated operational time is **approximately 15 minutes** per 5200mAh battery. The use of two batteries in parallel would double this runtime to **~30 minutes**.

Block diagram:

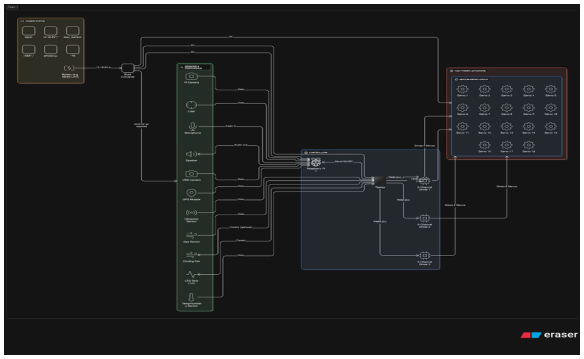

Fig.17: Circuit representation

c. Sensor Fusion and Communication

- SARAH integrates environmental sensors (gas concentration, temperature, humidity, sound) into its decision pipeline, with threshold-based alerts for immediate hazard notifications like toxic gas spikes or abnormal temperature rises.

- Sensor readings also feed a lightweight ML classifier to distinguish normal background variations from true hazards, while microphone audio cues (crying, tapping) are either relayed live or processed for anomaly detection.

- For communication, SARAH uses Wi-Fi as the primary link for high-bandwidth infrared video and telemetry, while LoRa serves as a fallback channel to ensure critical status and victim alerts can still be transmitted in obstructed or underground environments.

  This multimodal data fusion and hybrid communication enhance SARAH's ability to detect victims and assess environmental risks, improving mission safety and situational awareness during rescue operations.