34374 IoT Hardware and PCB Design
Exercise 9 - GNSS

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Part 1: System Design & Analysis

A. Module Theory & Pin Analysis

1. VCC & V_IO

- VCC Function: The VCC pin is the main voltage supply. It provides power to the module's core and RF (Radio Frequency) domains.
- V_IO Function: The V_IO pin is the IO voltage supply. It supplies power to all the digital IOs, the clock, and the backup domain (including the Battery-Backed RAM).
- V_IO Ranges & Selection: The V_IO pin supports two voltage ranges, which are physically selected using the VIO_SEL pin (pin 15):
  - 1.8V Range (1.76V to 1.98V): Connect the VIO_SEL pin to GND.
  - 3.3V Range (2.7V to 3.6V): Leave the VIO_SEL pin open (not connected).
- Project VIO_SEL Configuration: Our project requires a 3.3V main rail. To make the digital IOs compatible with this 3.3V rail, the VIO_SEL pin must be left open.
- Simplest Powering Method: Since our 3.3V rail is compatible with both the VCC operating range (1.76V - 5.5V) and the V_IO operating range (2.7V - 3.6V, when VIO_SEL is open), the simplest method is to connect the 3.3V LDO output to both the VCC and V_IO pins.

2. V_BCKP Analysis

- V_BCKP Function & Benefit: V_BCKP is the backup voltage supply pin. Its function is to power the backup domain (which includes the Real-Time Clock (RTC) and the Battery-Backed RAM (BBR)) when the main power (VCC and V_IO) is removed.

  The primary user benefit is a significantly faster Time-To-First-Fix (TTFF). By maintaining the RTC and satellite orbit data (ephemeris/almanac) in the BBR, the module can perform a hot start or warm start (∼5s) instead of a cold start (∼60s).

- RTC Backup Circuit Analysis: The diagram shows a charging circuit for the specified MS621FE rechargeable coin cell.
  - D2 (Diode): This is a steering diode. It allows the 3.3V rail to charge the battery B1 but prevents the battery from back-powering the entire 3.3V rail when the main supply is off.
  - R5 (Resistor): This is a current-limiting resistor. It protects the rechargeable MS621FE battery by providing a safe, low "trickle charge" current from the 3.3V rail.
  - C3 (Capacitor): This is a decoupling capacitor (1.0uF) for the V_BACKUP rail. It helps stabilize the backup voltage and filter out noise.
- Why Circuit is Necessary: We cannot simply connect the 3.3V rail, battery, and V_BCKP pin together for two main reasons:
  1. Back-Powering: The battery would try to power the entire 3.3V rail when the main LDO is off, draining itself almost instantly. The diode D2 prevents this.
  2. Uncontrolled Charging: Connecting the 3.3V rail directly to the rechargeable battery would create a high, uncontrolled charging current, which would destroy the battery. The resistor R5 prevents this.
- When Not Needed: This entire backup circuit is not needed if the application does not require a fast TTFF and can tolerate a cold start every time it powers on. In that case the V_BCKP pin can be left unconnected.

3. RF & Antenna Pins

- RF_IN Function: This is the GNSS signal input pin. It is the 50-ohm impedance-matched port where the signal from the external antenna is fed into the module.
- LNA_EN & VCC_RF Function: These pins work together to support an active antenna, which has its own internal amplifier (LNA) and requires power.
  - VCC_RF (pin 14): This is an output voltage pin. It provides a filtered voltage (derived from VCC) that can be used as the power source for an external active antenna.
  - LNA_EN (pin 13): This is an output control pin. It is used to enable or disable the external active antenna's LNA. The module can pull this pin low (sleep modes) to turn off the external LNA and save power.

4. Status & Interface Pins

- Pin Purposes:
  - TIMEPULSE (pin 4): An output pin that generates a time pulse signal with a configurable frequency. It is used for precise time synchronization.
  - RESET_N (pin 9): An active-low system reset pin. Driving it low for at least 1ms triggers a full hardware reset, clears the BBR, and forces a cold start.
  - SAFEBOOT_N (pin 18): An active-low pin used to put the receiver into safeboot mode at startup, which is used for service, updates, and reconfiguration.

  - EXTINT (pin 5): An external interrupt input pin. It can be used to wake the module from sleep or for the "Time mark" feature (to precisely log the time of an external event).

- TXD & RXD Function: These are the Transmit Data (output) and Receive Data (input) pins for the module's UART serial communication interface.

- Communication Protocol & Baud Rate:
  - Protocol: The module supports multiple protocols including NMEA, UBX, and RTCM.
  - Default Baud Rate: The default UART setting is 9600 baud.

B. System Design & Calculations

1. LDO Selection

- Peak & Inrush Current:
  - Peak Acquisition Current: The typical peak current during fix attempt for the default 3-GNSS configuration (at 3.0V) is 9.5 mA.
  - Maximum Inrush Current: The datasheet warns that "The inrush current can go up to 100 mA at startup". The LDO must be able to handle this peak.

- LDO Selection:
  - Requirements: 5V input, 3.3V output, and able to supply at least 100mA peak current.
  - Part Number: AP2112K-3.3TRG1.
  - Justification: This LDO accepts a 5V input voltage, provides a fixed 3.3V output, and can supply up to 600mA. This easily meets both the $\sim$10mA operating current and the 100mA inrush current requirement.

2. RF Design (Active vs. Passive)

- Design Choice: The design will not support an active antenna, but will be compatible with a passive one.

- Justification:
  1. Product Requirement: The product specification explicitly requires support for *either* a passive or an active antenna.
  2. Power: A passive antenna won't draw any DC power.
  3. Performance: An active antenna integrates an LNA at the antenna element, amplifying the weak GNSS signal. This generally provides a better signal-to-noise ratio (SNR) than a passive antenna. However, we choose to weigh the power consumption and BOM size higher than the performance.
  4. Module Support: We have chosen to add I2C communication as a primary benefit instead of the active antenna.