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Senor Design Project
EEC 134B Winter 18'
App Note/Tutorial on
Component Selection

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I. Introduction

During our FMCW Radar System design, determining which components to use on baseband and RF PCB's was the most difficult part of the project. Remember, you will actually be selecting components available on the market today, in small (sometimes individual) quantities. Often, both active and passive components aren't available in such small amounts, and if they are, it is often more expensive and takes longer to deliver. While price is important, it is not the only aspect of component selection. Most importantly, understanding the functionality of each part, and how it contributes to your overall system is necessary to understand. For this reason, I will suggest multiple techniques and strategies to implement throughout your EEC 134A & B Senior Design experience.

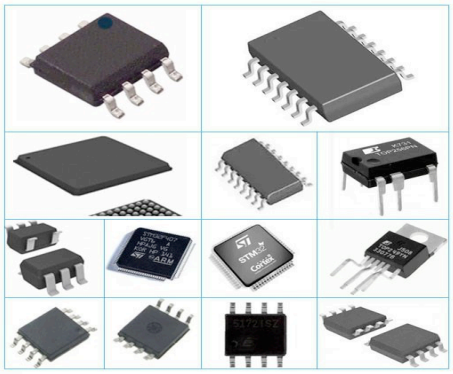

Figure 1: Electronics Components & Integrated Circuits

II. Advice Throughout Quarters

- Attend Lecture & Pay Attention in Quarter 1 Lectures to learn about what you're looking for in each component

- Search Online for vendors who distribute AVAILABLE individual RF & Baseband components for easy ordering and delivery (refer to list provided below)

- Become Familiar with Reading Component data sheets to find optimum component parameters

- Use all possible resources, Ebay, Amazon, Github, Reddit, Cofee Can Radar Blogs, etc. to help find new designs and approaches.

Reference Website: Tin can Radar blog
http://glcharvat.com/tincan/?page_id=6

Here is a vendor reference from LEO on GitHub that is very helpful.

https://github.com/ucdart/UCD-EEC134/blob/master/support/vendors-list/vendors-list.pdf

III. Advice Per Component

TEENSY- Description: Microcontroller with USB port connection, used for on-board signal generation and/or processing in a circuit or larger system. Teensy's can be used in many electronics projects and is what we used to generate a triangle wave signal in our final Radar system. An example image is shown below.

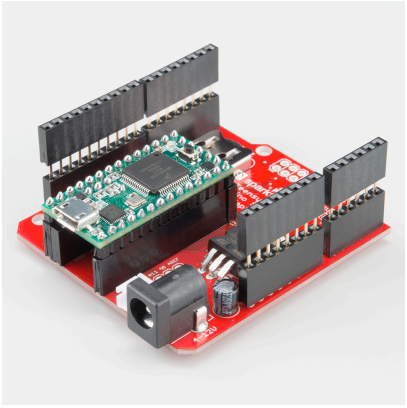

Figure 3: Teensy Microcontroller
Source: Sparkfun Electronics

Ideal Teensy Specs

- High Resolution ADC's (8-32 bit)
- Low Power Consumption
- High Voltage Tolerance
- Low Size, Weight, Cost
- Compatible with previous Teensy Versions Code
- Compatible with other Hardware Components
- https://cdn.sparkfun.com/datasheets/Dev/Arduino/Boards/K20P64M72SF1.pdf

Voltage Controlled Oscillator: Also known as a VCO, a component which produces an oscillation frequency depending on the input voltage. A critical component in any system, order this component early.

Figure 4: MAX2750EUA+ VCO
Source: Digikey Electronics

Ideal VCO Specs

- Pay attention to Output Power Level within your signal chain
- Watch for SINGLE VS. DIVIDED OUTPUT PORTS
- Output Frequency with respect to Vcc (supply voltage)
- **PHASE NOISE PERFORMANCE**
- Phase noise performance is defined as short, rapid fluctuations in the phase of a signal's waveform which causes **oscillations.** Also, the phase noise can be due to acceleration sensitivity of the crystal oscillator.

- https://www.mouser.com/ds/2/256/MAX2750-MAX2752-69221.pdf

Power Splitter: An RF Power splitter is a device which accepts an input signal and delivers multiple output signals with specific amplitude and phase characteristics (mini-circuits).

Figure 5: SP-2U1+ Splitter
Source: Mini-Circuits Electronics

Ideal Splitter Specs

- Used in Q1: Mini-Circuit ZX10-2-332-S+ power splitter/combiner
- Used in our case to combine/merge signals from two outputs to one input port
- Want low Insertion Loss
- Want low Current Leakage from port-to-port
- https://www.minicircuits.com/app/AN10-006.pdf

Attenuator: As the name implies, the attenuator is meant to reduce the power of the signal from one point in the circuit to another. In addition, attenuators lower the voltage, dissipate power, and improve impedance matching. Be careful which attenuator you order, we ordered one that was almost impossible to solder onto our PCB.

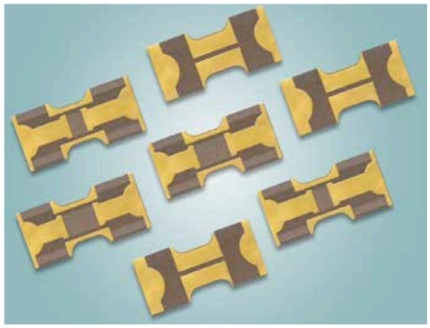

Figure 6: Example Attenuator
Source: Mini-Circuits Electronics

Ideal Attenuator Specs

-Used in Q1: Mini-Circuits VAT-3+ 3 dB RF attenuator
- Careful to choose a fixed attenuator versus switched or continuous
-Determine what level attenuator you need depending on specs of components before and after attenuator

Source: Lab Manual 4 Xiaoguang "Leo" Liu

Power Amplifier: The power amplifier is the component in your signal chain which Drives the signal power high before antenna transmission. You definitely want a high gain amplifier, but also have to be careful the component doesn't saturate due to its 1dB compression point.

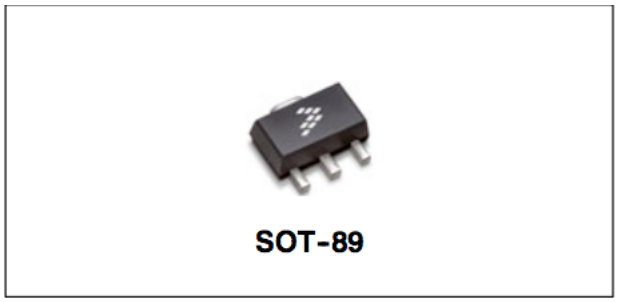

Figure 7: Example Power Amplifier
Source: Freescale Electronics

Ideal Power Amplifier Characteristics

- Used in Q1:**Mini-Circuits ZX60-272LN-S+ amplifier**
- Last stage before Tx Antenna
- Want high Output Power, decent power efficiency, & linearity
- Noise of less concern
- Important Parameters: Noise Figure, BW, gain, compression points, intermodulation
- https://www.mouser.com/ds/2/268/S71291-242235.pdf

Table 2: ZX60-272LN-S+ Typical Specifications.

Frequency range	2300 – 2700 MHz
Noise figure	0.8 dB
Gain	14 dB
P1dB	18.5 dBm
OIP3	31.5 dBm
Input VSWR	1.2
Supply voltage	5 V
Supply current	55 mA

Figure 8: Example Power Amplifier Specs

Tx Antenna: Consider many different types of Antennas for transmission. It comes down to testing and experimentation to determine which one is best. Good Luck!

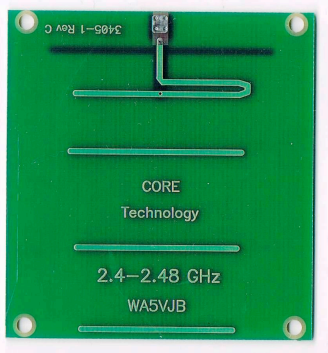

Figure 9: Yagi Antenna
Source: Ebay

Ideal Antenna Characteristics

- Focused Directivity
- High Gain
- Impedance Matching
- Large Bandwidth
- http://www.ti.com/lit/an/swra350/swra350.pdf

Rx Antenna: Consider many different types of Antennas for Receiving. It comes down to testing and experimentation to determine which one is best. Good Luck!

- http://www.wa5vjb.com/products6.html
  PATCH ANTENNA

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

Figure 2: Friis Transmission Equation

Referring to Figure 1,
Pt = power (dBm)
Gt = Gr = gain of transmitting and receiving antenna
λ = wavelength of system, using c = λf, when c = speed of light and f = operating frequency
σ = cross section of target, in our case it was 0.09m2.
R = range of target
Pr = received power (dBm)

Figure 10: Friis Transmission Equation
Source: Lab Manual 4 Xiaoguang "Leo" Liu

Low Noise Amplifier (LNA): This component is meant to filter out noise after the receiving antenna in your signal chain. The noise figure is the most important parameter of this component.

TAMP-272LN+

CASE STYLE: JQ1382

Figure 11: TAMP-272LN+ LNA
Source: Mini-Circuits

- First stage after Rx to minimize noise
- Want smallest NF possible
- Moderate gain & efficiency ok
- Gain not as important as in power amplifier
- Pay attention to P1dB Compression point
- Pay attention to IP3 point

- https://www.mouser.com/ds/2/472/201593A-693252.pdf

RF Mixer: The function of an RF mixer is to shift the frequency spectrum of the incoming signal. Essentially it modulates or demodulates the signal. This is also a very important component in your signal chain.

SIM-63LH+

CASE STYLE: HV1195

Figure 12: SIM-63LH+ Mixer
Source: Mini-Circuits

- Simply stated, there are three basic steps to choosing a mixer: (1) Deciding on a surface-mount, connector, or plug-in version. (2) Selecting the mixer "Level", which is the LO (local oscillator) drive power in dBm required for the application. (3) Picking a model that extends over the frequency range involved.
- Make sure the mixer is the right Level (ours was level 10) corresponding to the incoming power level
- https://www.minicircuits.com/pdfs/SIM-63LH+.pdf

- http://www.analog.com/en/products/rf-microwave/mixers/rf-mixers-w-integrated-los/adl5365.html?doc=ADL5365.pdf#product-overview

Baseband Amplifier: The baseband amplifier is used at the receiving end of the radar system to amplify the signal enough to be able to process it at the ADC. Gain is probably the most important factor.

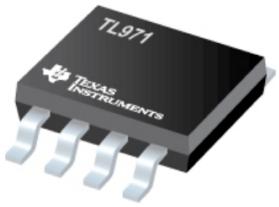

Figure 13: TL917 Baseband Amplifier
Source: Texas Instruments

- Low Gain & Phase Margin
- High Voltage output swing
- Low Noise Level & distortion
- High Gain
- Low power consumption
- Compatible operating frequency range
- https://datasheets.maximintegrated.com/en/ds/MAX2242.pdf

Analog-to-Digital Converter (ADC): The ADC is the signal processing workhorse of the system. It discretizes the signal which allows the user to process and interpret the signal data.

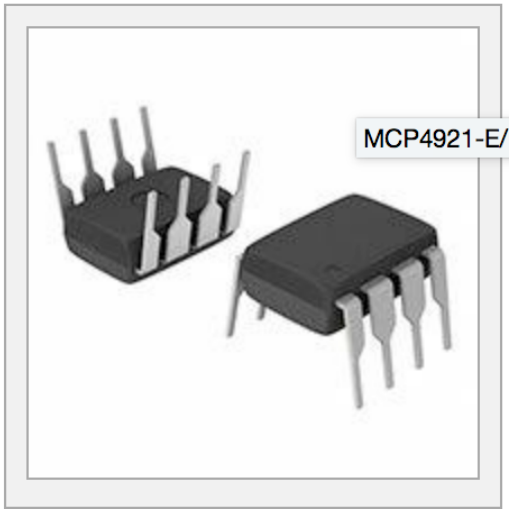

Figure 14: MCP4921-E/P-ND ADC
Source: Digikey Electronics

- High Resolution (4-12 bit)
- Low cost
- Low power consumption
- Compatible Operating Voltage
- http://www.linear.com/product/LTC6400-14
- Low Harmonic Distortion