Final Project
Analog Front-End Circuits Design

I. Objectives

1. To understand the manufacturing process of circuit implementation on Printed Circuit Board (PCB).
2. To familiarize with the construction and characteristics of the analog front-end circuits.
3. To implement the analog front-end circuits with PCB.

II. Components and Instruments

1. Components
   (1) OPAMP IC: LM324 ×1
   (2) ADC IC: ADC0804 ×1
   (3) DAC IC: DAC0832 ×1
   (4) Capacitor: 150 pF ×1, 0.01 μFx3, 0.1 μFx3, 10 μF ×4, 100 μF ×3
   (5) Resistor: 3.3 kΩ ×2, 4.7 kΩ ×2, 10 kΩ ×1, 47 kΩ ×3,100 kΩ ×6, 120 kΩ ×1, 1 MΩ ×1
   (6) Variable resistor: 10kΩ ×1
   (7) Switch: DIP switch ×1
2. Instruments
   (1) DC power supply (Keysight E36311A)
   (2) Digital multimeter (Keysight 34450A)
   (3) Oscilloscope (Agilent MSOX 2014A)

III. Reading

1. Section 11-7 of “Microelectronics Circuits 6th edition, Sedra/Smith”.
2. Experiment 11 of “Laboratory Explorations for Microelectronic Circuits 4th edition, Kenneth C. Smith”.
3. Chapter 2 of “Wireless Transceiver Design: Mastering the Design of Modern Wireless Equipment and Systems, 2nd Edition, A. Luzzatto, M. Haridim” (https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781119315650.ch2)

IV. Preparation

1. Introduction

In the modern wireless transceiver for mobile device, there are three parts including radio-frequency (RF) front end, analog front end (AFE), and digital signal processing (DSP) as shown in Fig. 1. To begin with the signal receiving, the RF front-end circuit receives the RF-band wireless signal by an antenna and then demodulates the RF-band signal to a baseband signal by a mixer. After that, in AFE, a low-pass filter (LPF) and an analog-to-digital converter (ADC) is applied to remove out-of-band distortions and digitizes the analog baseband signal, respectively. With the digital signal, lots of functions can be conducted in a DSP including arithmetic operation for specific application, encryption for security, and so forth. To transmit the result as a wireless signal, the DSP digital output is converted to an analog signal by a digital-to-analog converter (DAC) and then a LPF is applied to remove spurious high-frequency replicas. Next, a mixer and an antenna is applied to modulate the baseband signal into RF-band signal and emit the wireless signal, respectively.

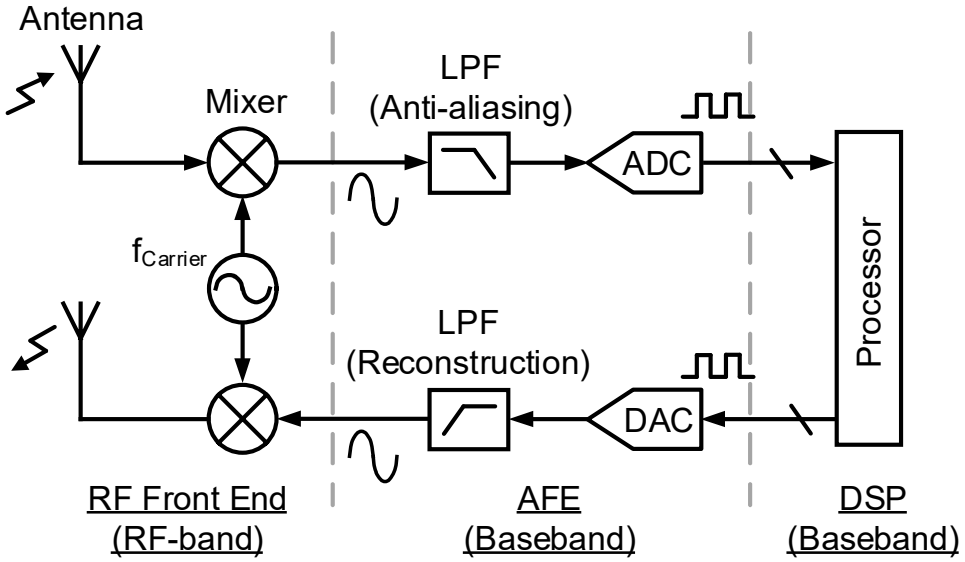

Fig. 1. The block diagram of a transceiver

For students, it's significant to understand the fundamentals of the transceiver as mentioned above. This final project presents prototype AFE circuits for baseband signal operation including an ADC, a DAC, and two LPFs.

Fig. 2(a) and (b) shows the schematic of anti-aliasing filter and reconstruction filter, respectively. The anti-aliasing filter is a first-order low-pass filter which eliminates signals out of Nyquist band of ADC. For ADC0804, the Nyquist band frequency is about 5 kHz owing to the ADC 10 kS/s conversion rate. Please design the labeled resistor R_1 shown in Fig. 2(a) for a desired 5-kHz 3-dB corner frequency of the anti-aliasing

low-pass filter. On the other hand, in Fig. 2(b), the reconstruction filter is a second-order low-pass filter which make the staircase DAC output signal be a smooth analog waveform. Please design the labeled resistor R_2 for a desired 6-dB corner frequency within 3.3 k~3.6 kHz.

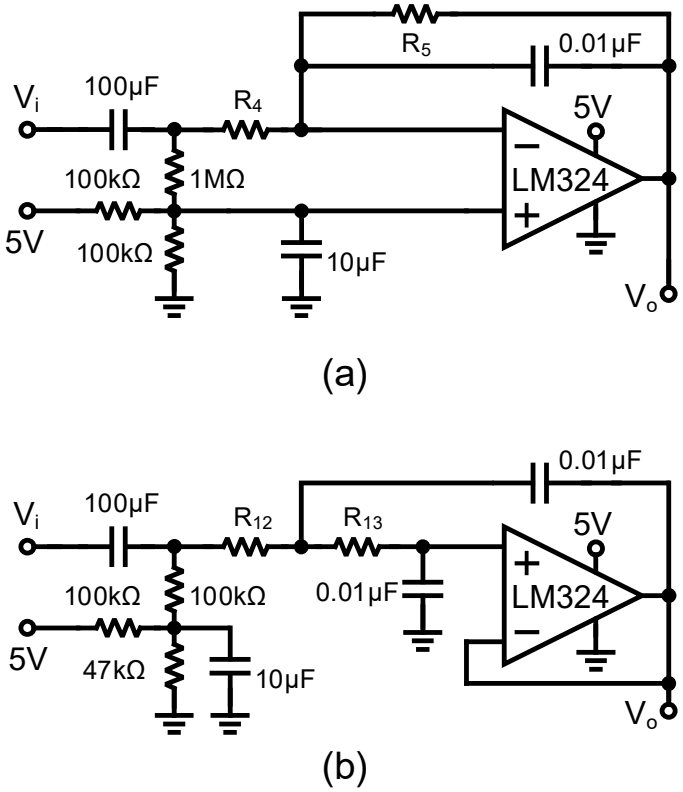

Fig. 2. Schematics of (a) the anti-aliasing filter and (b) the reconstruction filter

Fig. 3 show the schematics of the peripheral circuits for ADC and DAC. Please note that the supply voltage for ADC and DAC is 5-V. A wrong supply voltage connection definitely sabotages the ADC or DAC and results in malfunctioning. Students are requested to input a 2-Vpp, 500Hz sinusoidal waveform to the designed AFE circuits and plot both input waveform (V_{IN}) and output waveform (V_{OUT}) on an oscilloscope.

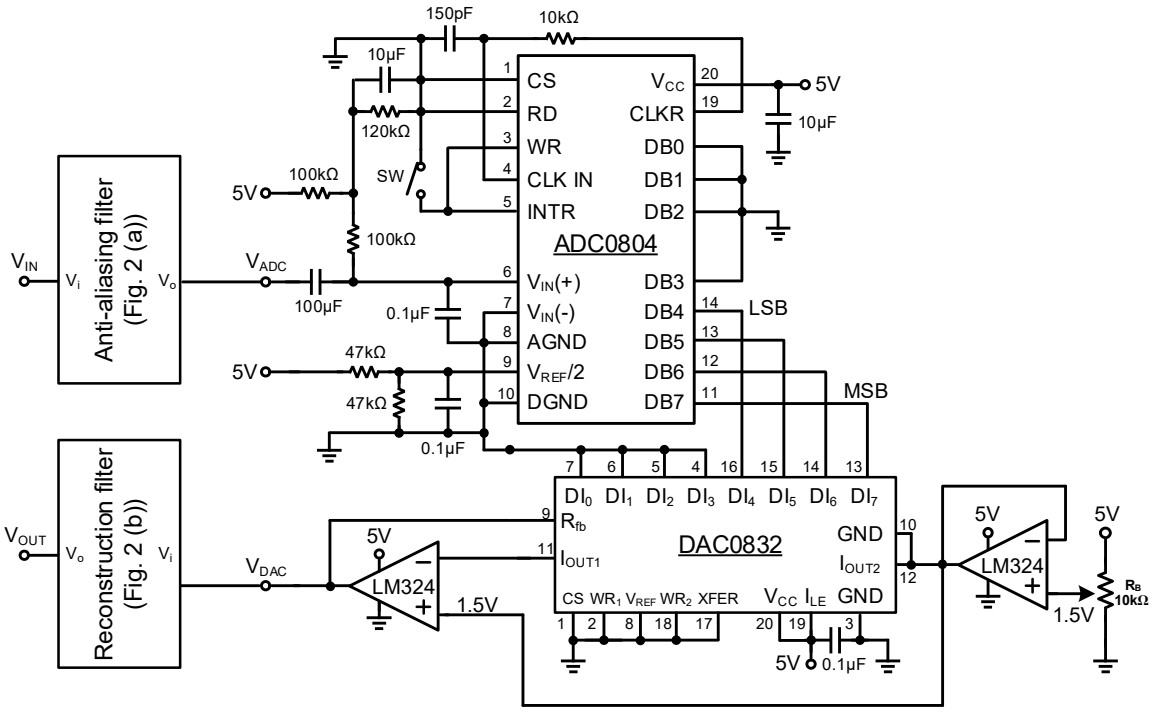

Fig. 3. Schematics of peripheral circuits for ADC and DAC

The designers should prepare all the listed components and implement the circuit of the AFE circuits on PCB. Students are suggested to solder components following the PCB layout shown in Fig. 4.

Table 1. List of components

Res.	Value (Ω)	Res.	Value (Ω)	Cap.	Value (F)	Cap.	Value (F)
R1	100k	R10	47k	C1	100μ	C10	0.01μ
R2	1M	R11	10k	C2	0.01μ	C11	0.01μ
R3	100k	R12	**TBD**	C3	10μ	C12	10μ
R4	**TBD**	R13	**TBD**	C4	100μ	C13	0.1μ
R5	**TBD**	R14	100k	C5	10μ	C14	10μ
R6	100k	R15	47k	C6	0.1μ		
R7	100k	R16	100k	C7	150p		
R8	120k	R17	10k	C8	0.1μ		
R9	47k	(Var.)		C9	100μ		

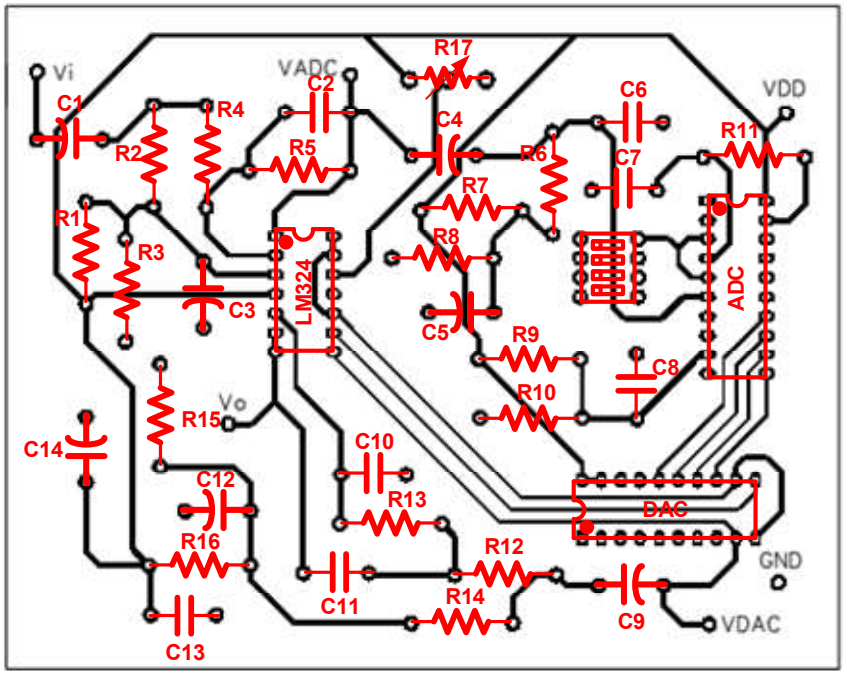

Fig. 4. PCB Layout of the AFE circuits

There are 3 notifications in Fig. 4:

a. Directions of the IC(LM324) and the capacitors
   - Fig. 4 show the **top view** of the PCB with the underneath routing wires on bottom layer. Pin 1 of LM324 is at the **top-left corner** of the IC, which is labeled with a spot (·) sign. The locations of the anodes and cathodes of the capacitors are all clearly labeled as shown in Fig. 4. However, if the electrolytic capacitor is not used in your design, the labels are negligible.

b. Black lines
   - The black lines are the wire lines on the bottom layer. Note that both of the power line (**VDD**, **GND**) and the signal line (**V_i**) are in black labels, they should be **connected from the top layer**.

c. Red labels
   - The components with red labels are the components **on the top layer**, while some of them should be designed by the designers including (R4, R5, R12 and R13). The values of predetermined components are **listed in Table 1**.

V. Exploration

1. Design of the filters shown in Fig. 4
   (1) Describe the design flow and verify that with PSPICE.
   (2) Complete Table 2.

Table 2. Design parameters of filters

	Resistance (ohm)	Corner frequency (Hz)
R4, R5		
R12, R13		

2. Measurement of the AFE circuits shown in Fig. 4
   (1) Please show the V_{OUT} waveform with a 2-Vpp, 500-Hz sinusoidal signal at V_{IN}.
   (2) Following the questions above, please show the FFT spectrum of V_{OUT} in (1).
   (3) Describe the FFT spectrum in (2) with detailed statements about the functions of two filters.

VI. Conclusion