Research on STM32-Based Signal Conditioning System Measurement System

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Abstract. The measurement of the signal modulation system is a vital part of channel transmission signal technology, which has a very important position in the signal communication quality assurance system. With the development of radio communications in modern radio technology, the research of AM and FM signal modulation measurement methods has become an important element in this field of research. This research is a signal modulation system using an STM32F407 microcontroller as the control core. The hardware of the system is mainly composed of a coherent demodulation circuit system and a comparator judgment circuit system, and the coherent demodulation circuit system is divided into AM demodulation circuit system and an FM demodulation circuit system. The frequency of the input signal was measured by a comparator, and the frequency change was used to initially determine the signal type. In which the modulating signal of AM signal was obtained by DDS generating separate orthogonal sine and cosine signals with the input signal through a series of operations, while the FM signal was operated with the sine signal. Finally, the amplitude and frequency information of the FM signal was obtained through the comparator, and finally reduced to the modulating signal of the FM signal. Output demodulated signal, its signal waveform without obvious distortion apparent phenomenon. Promotes the prospect of using the calibration of AM and FM signal generators in the field of communication.

Keywords: Modulation system measurement, Coherent demodulation, Demodulation circuit system.

1. Introduction

Nowadays, signal modulation measurement technology is developing rapidly in China and abroad. In the current technological development, there are only two modes of signal modulation in the development: analog modulation and digital modulation [1-3]. Among them, analog modulation generally uses two modulation methods: angle modulation (nonlinear modulation) and amplitude modulation (linear modulation) [4-5]. Angular modulation can be divided into frequency modulation and phase modulation. Digital modulation can also be divided into amplitude modulation and angle modulation, compared with analog modulation, digital modulation uses a digital signal modulation signal, more conducive to the processing of software systems, with strong anti-interference. Signal modulation parties are widely used in the field of electronic communication. Modulation methods are constantly being derived and techniques for the development of signal modulation communication systems are emerging. The most popular technology is a DDS technology-based communication signal modulation. The DDS series AD9854 in this study is a direct digital frequency synthesis, and the frequency, amplitude, and phase of the output signal can be adjusted independently [6]. The rapid development of signal modulation technology has gradually realized the automatic identification and reception of signals, as well as the demodulation of signals [7-8].

2. Working Principle and Design Solution

2.1. Working principle of modulation system measurement

The signal modulation system measurement device gave a display signal source output of the measured signal modulation system and other parameters, through the signal modulation system measurement device, accurately identifies and display the modulation of the measured signal, output demodulated signal, and display on the oscilloscope. The measurement system is shown in Figure 1.

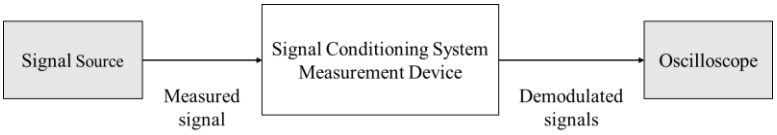


Figure 1. Block diagram of signal conditioning measurement system

The measured signal was an ordinary monotone amplitude modulation (AM) voltage u_{AM} with a voltage peak-to-peak value of 100mV, a carrier frequency of 10MHz, and a modulated signal with a frequency of 1~3kHz sinusoidal signal. Measurement of the modulation amplitude m_a of the display u_{AM}, the absolute value of error $|\triangle| \leq 0.1$; observation of the output demodulated signal, demodulated signal waveform without significant distortion. The measured signal was a single-tone FM (FM) voltage u_{FM} with a voltage peak-to-peak value of 100mV, which was measured by the same signal modulation system, yielding a phenomenon similar to that of ordinary single-tone amplitude modulation (AM). The measured signal was a high-frequency voltage u_m with a carrier voltage peak value of 100mV, and its carrier frequency range was 10MHz~30MHz (frequency step interval 0.5MHz). u_m is a modulated waveform (AM or FM waveform), and the modulated signal is a sinusoidal signal of a frequency within the frequency range of 5 kHz to 10 kHz (frequency step interval 1 kHz). The measurement device determines whether u_m is an AM, FM, or unmodulated carrier waveform by autonomously identifying u_m the modulation method. The measurement showed the modulation system of u_m (m_a or m_f), and the measurement error met the requirements of monophonic amplitude modulation (AM) and monophonic frequency modulation (FM); when the measured signal was an FM waveform, the demodulated signal was output, and the waveform was not significantly distorted.

2.2. Design solutions for regulating system measurements

(1) Coherent demodulation is used to demodulate the AM or FM wave of the measured signal. To recover the original baseband signal without distortion, the receiver has to provide a local carrier (called the coherent carrier) that was strictly synchronized with the received tuned carrier (same frequency and same phase), which is multiplied with the received tuned signal, and then the low-frequency component is removed by a low-pass filter to obtain the original baseband modulated signal [9]. But the coherent demodulator is suitable for the demodulation of all linear modulated signals, i.e., for AM, DSB, SSB, and VSB. In addition, considering the influence of circuit noise signals and the complexity of the input signal, the use of coherent demodulation would better avoid the influence of extraneous factors on this study.

(2) The TLV3501 high-speed comparator has a significant processing effect on the waveform of the measured signal. The single power supplied input avoids setting the power supply bias and allows a wide frequency band of the input signal. After the input signal passed through the AD8009 amplifier and passed through the TLV3501 comparator if the output signal was square wave signal, the input signal was FM, and if the output signal did not change, the input signal was AM or unmodulated signal.

(3) In the main control unit, the STM32F407 has three 12-bit precision fast ADCs, each of which meets multiple channels [10]; the F407 also has two 12-bit DACs; the F407 also has two DMA controllers, each of which has its channel, and each of which has a different stream, so that various peripheral-to-memory, memory-to-peripheral, and other different needs can be realized, which is more conducive to the implementation of the circuit.

(4) The frequency synthesis of AM and FM waves, as the circuit signal source provided the carrier for quadrature modulation, the AD9854 was selected for processing with 2 high-speed DACs, and the frequency, amplitude, and phase of the output signal were adjustable independently. As long as the preset value in the phase register differs by 90°, the phase difference between the two output

signals is 90° and the quadrature signal would be generated. This way the signal source would provide the carrier for quadrature modulation.

The design of the overall system circuit is shown in Figure 2.

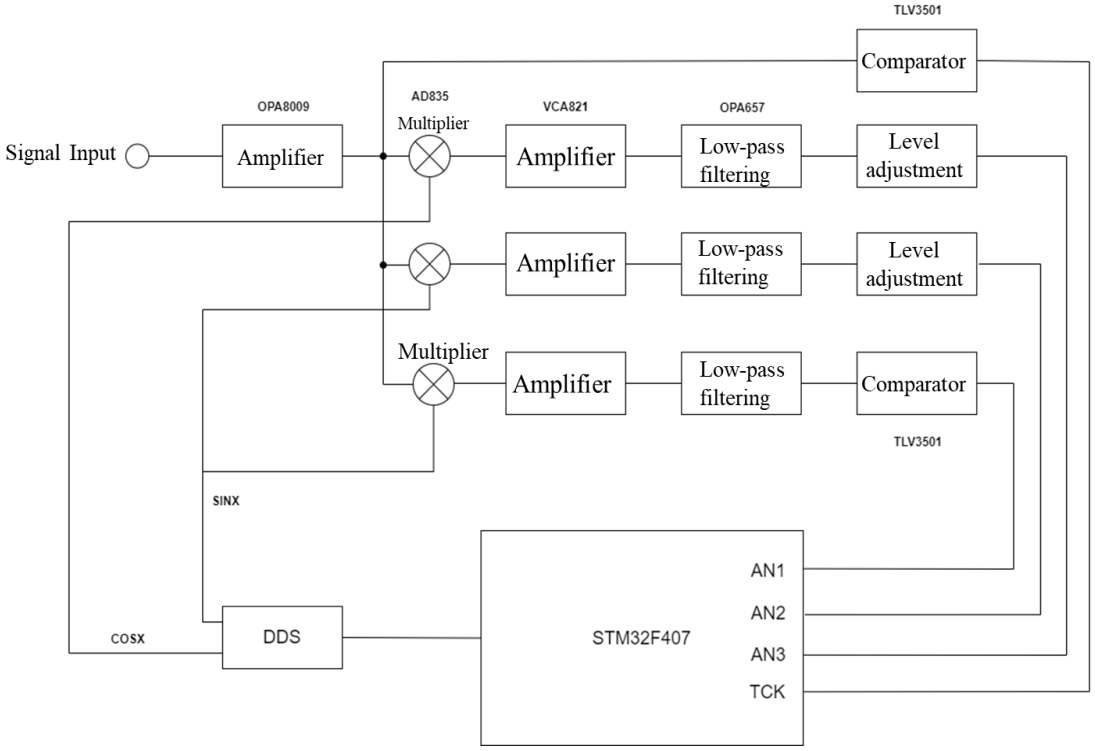


Figure 2. The overall system circuits

2.3. Data parameter calculation

(1) For AM: Amplitude modulation factor (modulation system).

$$m_a = \frac{|m(t)|_{\max} / A_m}{A_0}, \tag{1}$$

Reflects the degree to which the modulated signal $m(t)$ changes the carrier amplitude. For monophonic sine: $m(t) = A_m \cos w_m t$ 。 Among the carriers: $c(t) = \cos w_c t$

Bilateral band modulation DSB: $S_{DSB}(t) = m(t)\cos w_c t$. The transmit power is used entirely for the useful signal, and the DC component is removed.

$$S_{DSB}(t) \cdot c(t) = \frac{1}{2} m(t) \cos 2w_c t + \frac{1}{2} m(t), \tag{2}$$

Including: $\frac{1}{2} m(t) \cos 2w_c t$ is low-pass filtering, $\frac{1}{2} m(t)$ is demodulation output

If the same frequency and different phases, therefore

$$m(t) \cos w_c t \cdot \cos(w_c t + \varphi) = \frac{1}{2} m(t)[\cos \varphi + \cos(2w_c t + \varphi)], \tag{3}$$

Single-sided band modulation.

$$S_{DSB}(t) = \frac{1}{2} A_m \cdot \cos(w_c - w_m)t + \frac{1}{2} A_m \cdot \cos(w_c + w_m)t, \tag{4}$$

Including: $A_m \cdot \cos(w_c - w_m)t$ is LSB, $A_m \cdot \cos(w_c + w_m)t$ is USB. Then,

$$S_{LSB}(t) = \frac{1}{2} A_m \cdot \cos w_m t \cdot \cos w_c t \pm \frac{1}{2} A_m \cdot \sin w_m t \cdot \sin w_c t, \tag{5}$$

(2) For FM, Monophonic FM:

$$S_{FM}(t) = A \cdot \cos[w_c t + m_f \sin w_m t], \tag{6}$$

FM index: $m_f = \frac{\Delta f}{f_m} = \frac{K_f A_m}{f_m}$ (maximum phase shift), the index includes ① FM transmission bandwidth ② FM power distribution ③ noise immunity performance.

FM spectrum: $S_{FM}(w) = \pi A \sum_{-\infty}^{+\infty} J_n(m_f)[\delta(w - w_c - nw_m) + \delta(w + w_c + nw_m)]$, an infinite number of multiple-sided frequencies w_c distributed on both sides of the carrier frequency component $w_c \pm nw_m$, whose amplitude depends on m_f.

FM bandwidth: $B_{FM} = 2(m_f + 1) f_m = 2\Delta f + 2 f_m$, whereby f_m is the highest frequency of $m(t)$. At $B_{FM} \approx 2 f_m$, $f_m \ll 1$, narrowband FM, at $B_{FM} \approx 2\Delta f$, $f_m \gg 1$, wideband FM.

FM signal demodulation (frequency discrimination): frequency wave with constant amplitude.

$$S_{FM}(t) = A \cdot \cos[w_c t + K_f \int m(\tau) d\tau], \tag{7}$$

Amplitude modulated frequency wave.

$$S_d(t) = -A \cdot [w_c t + K_f m(\tau)] \sin[w_c t + K_f \int m(\tau) d\tau], \tag{8}$$

3. Core circuit design and underlying software porting

3.1. Core hardware circuit design

3.1.1 Signal Generator

For quadrature signal generation, the AD9854 has 2 high-speed DACs, and the frequency, amplitude, and phase of the output signals can all be independently adjusted. As long as the preset values in the phase register are 90° apart, the phase difference between the 2 output signals is 90° and the quadrature signal is generated. This way the signal source can be supplied with a carrier wave for quadrature modulation. The modulating signal: $f(t) \cos w_c t = \frac{1}{2}[F(w - w_c) + F(w + w_c)]$, whereby $w_c t$ is the carrier signal.

3.1.2 Amplifier circuit

The AD8009 high-voltage swing rate reduces the voltage-swing limiting effect and enables a large signal bandwidth of 440 MHz to meet the needs of high-resolution video graphics systems. Signal quality remains high over the entire wide bandwidth range, with a worst-case distortion of -40 dBc (250 MHz, G=+10, 1V peak-to-peak). This distortion performance, combined with the current feedback structure, allows the AD8009 to be used flexibly as a gain stage amplifier in IF/RF signal chains. The amplifier in this design, the AD8009, amplifies the input signal. The magnification factor,

$$K = 1 + \frac{R_f}{R_1} = 10.4, \tag{9}$$

VCA821 controllable gain amplifier module. Gain adjustment mode: ①Manual adjustment (default) ②DAC program control (control voltage range is 0~2V, the corresponding gain range is 20~40dB). Where high gain accuracy: 20dB±0.3dB. the module can input single-ended or differential signals. Due to the coupling capacitance, the module is not suitable for use at low frequencies. In this study, the amplifier VCA821 amplifies the signal input through the amplifier AD8009 and the DDS chip coherent signal through the multiplier operation.

3.1.3 Comparator Circuit

The TLV3501 is a high-speed comparator. It can be used for waveform shaping of input signals and outputting TTL level signals. It has a fast 4.5ns propagation delay time and can be powered by a single 5V supply, making it ideal for high-speed comparison circuits. It has a wide input signal frequency band and can input signals from 0.1Hz to 230MHz. The circuit comes with a fixed threshold voltage comparison, making the output square wave almost jitter-free. This module can be used in systems such as waveform shaping and frequency and other time quantities processing. The TTL level square wave signal, when the input duty cycle variable rectangular wave signal outputs the same input duty cycle size of the TTL level rectangular wave signal. After the input signal passes through the AD8009 amplifier and passes through the TLV3501 comparator if the output signal is a square wave signal, the input signal is FM, and if the output signal does not change, the input signal is AM or trim signal.

3.2. Underlying software porting

Create top and bottom project files on Keil uVision5 software, so that a series of digital information converted by the hardware is ported to the LCD by the software device to output relevant information, top and bottom files are shown in Table 1.

Table 1. Display top-level and bottom-level files

Display (LCD) software engineering files				
Top-level documents	USER	HARDWARE	SYSTEM	CORE
Underlying Documents	main. c	led. c	delay. c	startup_stm32f40_41xxx. s
	stm32fxx_it.c	LCD. c	sys. c	
	system_stm32f4xx. c	adc. c	usart. c	
		BSP. c		
		dft. c		
		DAC. c		
		AD9854. c		

4. Results

4.1. The establishment of test protocols

The method of separate debugging and then overall debugging, and the combination of hardware testing and software testing was adopted to improve the debugging efficiency.

4.2. Hardware Testing

Throughout the process, the hardware circuits were first built-in separate modules and successfully tested separately, then the discrete modules were built together to test the overall function, and then tested jointly. After the test, our coherent demodulation circuit and comparator judgment circuit both works properly.

(1) Frequency and amplitude of the amplifier OPA8009 when the input signal is a 100mV sine signal. The test results are shown in Table 2.

Table 2. Frequency and amplitude measurement of amplifier OPA8009

Amplifier OPA8009		Input 100mV sine wave			
Frequency	1KHz	10KHz	500KHz	1MHz	5MHz
Voltage	1.01V	1V	1V	1V	0.95V
Frequency	10MHz	12MHz	14MHz	16MHz	17MHz
Voltage	0.88V	0.83V	0.77V	0.73V	0.707V

At this time the amplifier OPA8009 passband is shown in Figure 3.

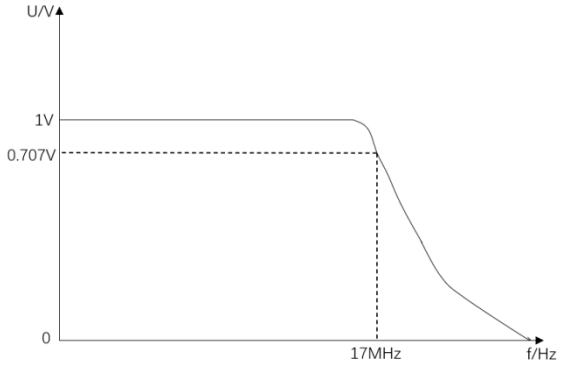


Figure 3. Amplifier OPA8009 passband

The voltage amplitude of the amplifier OPA8009 was found to be 0.707V when the input signal was

a 100mV sine signal at a frequency of 17MHz.

(2) When the input signal is a 100mV sine signal, the frequency and amplitude of the low-pass filter AD657 are shown in Table 3.

Table 3. Frequency and amplitude of low-pass filter AD657

Low-pass filter AD657		Input 100mV sine wave			
Frequency	1KHz	2KHz	3KHz	4KHz	5KHz
Voltage	107mV	106mV	105mV	103mV	101mV
Frequency	10KHz	12KHz	15KHz	17KHz	18KHz
Voltage	85mV	78mV	78mV	72mV	70.8mV

(3) The square waveform of each frequency of the TLV3051 voltage comparator is shown in Figure 4.

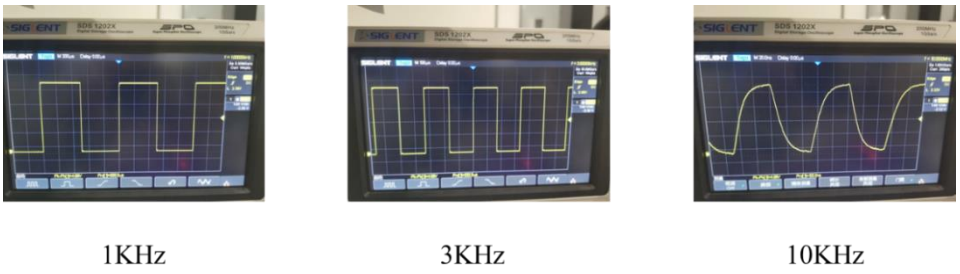


Figure 4. TLV3051 voltage comparator square waveforms for each frequency

It was found that when the input signal was a 100mV sine signal, the low-frequency signal could be well rectified and the high-frequency signal square wave would be distorted.

4.3. Software simulation testing

The software test was chosen to test directly on the built hardware, and the operating data were viewed and analyzed with the help of the serial debug window, and the LCD showed the result data of the above hardware.

5. Summary analysis of research effectiveness

5.1. AM modulated signal demodulation

The demodulation of the monophonic AM modulated signal is shown by an oscilloscope with the relevant waveforms in Figure 5.

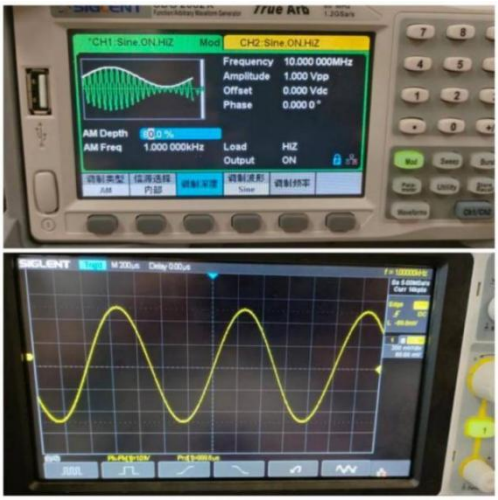


Figure 5. AM modulated signal demodulation display

The waveform demodulated from the monophonic AM modulated signal was found by the oscilloscope to be a stable sinusoidal signal with a peak-to-peak value of 1.01 V and a frequency of 1 kHz. Measurement display u_{AM} of the adjustment range m_a, the absolute value of the error between 0.093 ~ 0.1, to meet the absolute value of the error $|\Delta| \leq 0.1$.

5.2. FM modulated signal demodulation

The demodulation of the monophonic FM-modulated signal is shown by an oscilloscope with the relevant waveforms in Figure 6.



Figure 6. FM-modulated signal demodulation display

As can be observed by the oscilloscope, a baseband signal was given to the FM modulated signal, and the information waveform containing the baseband signal was demodulated by the modulator through the carrier as a sine wave pulse sequence and the modulated carrier contained the baseband signal. The absolute value of error is between 0.238 and 0.3, which satisfies the absolute value of error $|\triangle| \leq 0.3$. The modem demodulation process is shown in Figure 7.

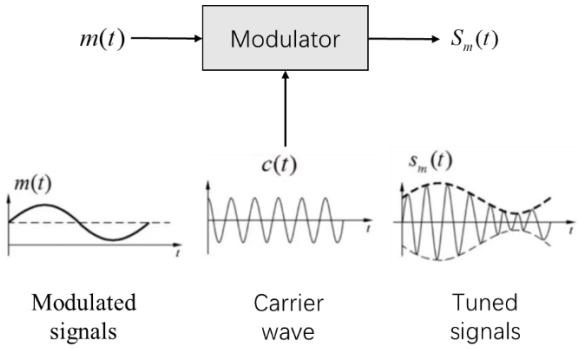


Figure 7. Modulation flow

5.3. Unknown signal type input

The unknown signal type could be identified automatically by the DDS module. The AD9854 has 2 high-speed DACs, and the frequency, amplitude, and phase of the output signals can be adjusted independently. As long as the preset values in the phase register are 90° apart, the phase difference between the 2 output signals is 90° and the quadrature signal is generated. This way the signal source can provide a carrier for quadrature modulation. That is, it would be possible to determine the monophonic AM or FM.

6. Conclusions

The signal modulation system measurement system in this research is very vital in the electronic pass. Measure the modulation amplitude of single-tone amplitude modulation (AM or FM) voltage, the absolute value of the error is within the range of technical requirements; and observe the output demodulated signal, the demodulated signal waveform without obvious distortion. It shows that the signal modulation system of this research experiment has practical value, and by modulating carrier signals of different frequencies, the baseband signals can be transferred to carriers of different frequency bands, which facilitates the simultaneous transmission of multiple different baseband signals. With the progress of communication technology and the development of modulation methods, the challenges in the mode of communication signal modulation are constantly faced.

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