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Design of 3mm Band Detector Indoor Calibration System

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Abstract

A 3mm band detector indoor calibration system is introduced in this paper, which is based on a STM32 embedded system. This embedded control system includes noise source control circuit, database circuit, a real time clock circuit, humidity and temperature sensor circuit, PS/2 interface circuit and SD card interface circuit. And a database, which contains radiation characteristics of metal targets, is built in this calibration system. Experiment results demonstrate that the indoor system could satisfy the requirement of 3 mm band detector calibration.

Keywords: *indoor calibration system, STM32 Embedded system, Database, Millimeter-wave detector*

1. Introduction

Millimeter-wave detectors, with small size, light weight and high-resolution, have obvious advantages and are adopted in civil and military applications [1]. A 3mm band indoor calibration system is used to test performances of 3mm band passive detectors in laboratory. A noise source produces radiation brightness temperature [2] and its output power is adjusted with an Electronic control attenuator to simulate the radiation brightness temperature difference between ground and metal target in different conditions, such as different backgrounds, different weathers, different detecting distances, different target sizes, etc. [3, 4]. A checked millimeter wave detector would receive the noise signal and output processing waveform and target recognition results [5, 6]. This calibration system block diagram is shown in Figure 1.

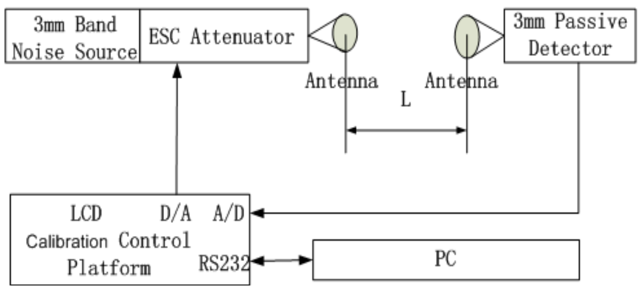

Figure 1. 3mm Band Calibration Platform System

2. System Function Design

A STM32F103ZET6 chip is adopted as core hardware to perform calibration control functions. The calibration control platform includes the switch control circuit of a 3mm band noise source, the ESC attenuator attenuation, LCD with a touch keyboard function, a database, STM32F103ZET6 embedded system and other modules [7], so the calibration control platform has the function of noise source radiation control, environmental temperature and humidity acquisition, touch LCD screen display, communicate with PC, real- time clock, SD card storage, database updating. The system control functional block diagram is shown in Figure 2.

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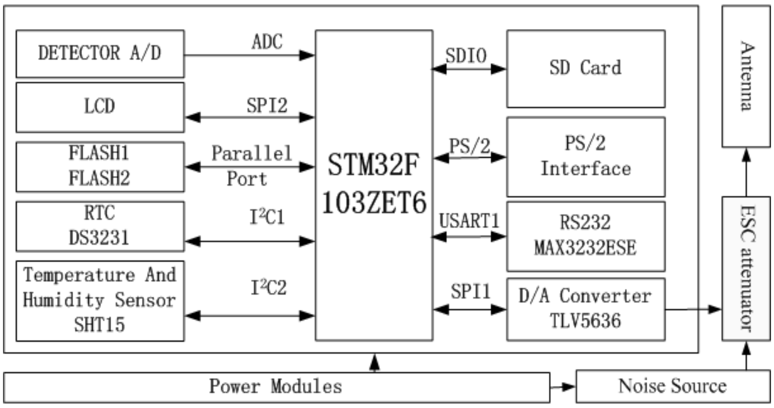

Figure 2. Embedded System Functional Block Diagram

STM32F103ZET6 MCU is ST Microelectronics ARM-based 32-bit large capacity enhanced products, with two SPI interfaces, two I^2C interfaces, FMC function module, etc. [14]. A DAC converter TLV5636 with SPI1 transforms digital control word from the MCU into an analog signal to control the ESC attenuator and radiation power, SPI2 is used as the input for touch screen through ADS7843. A temperature/humidity sensor SHT15 [8] is connected to STM32 with I^2C1 and DS3231 [9] real-time clock occupies I^2C2. 256MB NAND Flash memory of HY27UF082G2B are extended by FSMC as a database to store target characteristics data and SD card is used as input/output device for this database. A mouse is connected with PS/2 interface. A host computer PC is communicated with STM32 by RS232.

This calibration control platform used directly adopts STM32 inbuilt ADC, the detector output voltage is directly connected to ADC input pins of STM32.

3. Hardware Circuit Design

The STM32 chip, produced by ST Company, has a high performance ARM Cortex-M3 core micro controller specifically for embedded applications [10]. It contains 512kB FLASH and 64kB SRAM, frequency up to 72MHz, with abundant peripheral interfaces, so it is very suitable for the control field. The system's function has been presented above. Detailed peripheral circuits are given as following.

3.1. Noise Source Control Circuit

The Embedded system control the electronic control attenuator through an external DAC LTV5636, and LTV5636 is communicated with the MCU via SPI [11]. Noise source is the core of the 3mm band passive detector indoor calibration system. It can generate 3mm band noise, and launch from antenna, and the radiation power would be measured by the antenna of the detector. Then the detector receives the radiation brightness temperature, which simulates reflection sky temperature from metal targets. The calibration system controls noise source's on and off and on/off duration, and the attenuator setting, which simulates the process of a passive detector and a metal target intersection, which would make the detector produce the waveform output similar to the actual detection. 3mm band noise source is a solid noise source from Ukraine, operating at 25V voltage and 120mA current. Noise source control voltage level is 0~5V, 0V is fully open and 5V is fully closed. Excess Noise Ratio is about 15.9~17dB at 91 ~98GHz. At 94GHz, the excess noise ratio is about 16.25dB. Circuit design is shown in Figure 3.SHT15 is a temperature/humidity sensor, which is used to measure environmental temperature and humidity parameters to compensate DAC output.

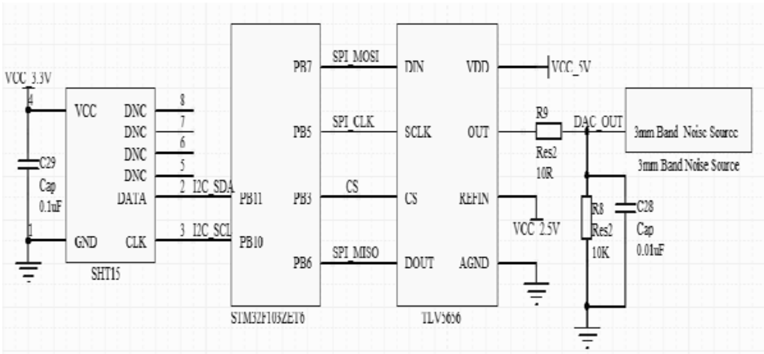

Figure 3. Noise Source Control Circuit

3.2. LCD Display Circuit and Control

In 3mm band calibration system, a touch LCD is adopted as a displayer and input. This LCD is in TFT structure integrated with SSD1289 driver chip and RAM memory [13]. In use, only power lines, address lines, signal lines and control lines are connected to MCU, and display information code is written to LCD's RAM and decoded by the driver chip, then is displayed on the LCD screen. This touch screen is resistive and a chip ADS7843 is used as a quantizer to quantize input voltage, and the quantize value is transferred to MCU through SPI2. Figure 4 shows the MCU interface and TFT LCD screen interface connection diagram. PG12 is the chip selected signal pin. PB0 is the PWM signal output pin, and MCU uses PB0 to control the LCD backlight. PG7 is the touch screen's interruption response signal pin. PB12, PB13, PB14, PB15 are SPI2 interfaces, and LCD screen's touch coordinate signal is transmitted to MCU through SPI2 interface. Figure 5 shows this LCD with 3.2 inch.

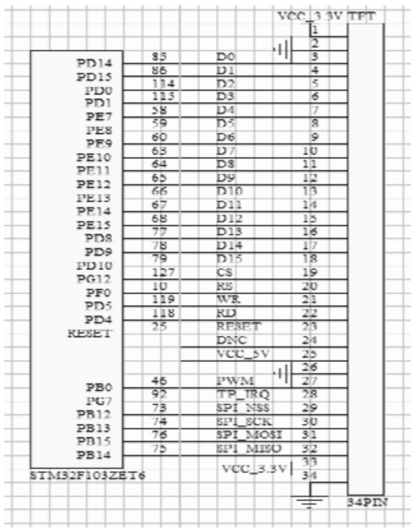

Figure 4. LCD Touch Screen Interface Circuit

Figure 5. 3.2 inch TFT Display LCD Screen HY32D

3.3. Real-time clock circuit

In this calibration indoor system, real-time clock is provided with DS3231, which is a high precision and low cost chip. It includes an integrated crystal oscillator with temperature compensation, and address and data are serially transferred through an I^2C bidirectional bus with SMT32 [12]. Real-time clock circuit is shown in Figure 6. VBAT is a reserve power, which could be a 3.6V battery or a 1.5F super capacitor. This pin is connected by a diode in parallel with an external 5V power supply in the circuit.

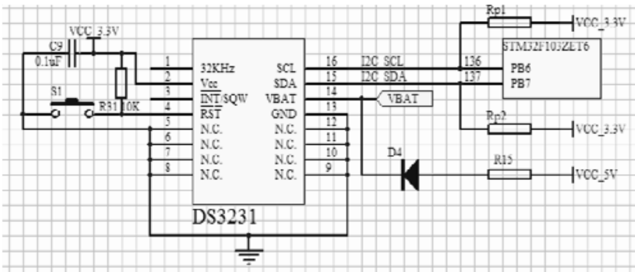

Figure 6. DS3231 Real-time Clock Circuit

3.4. PS/2 Interface Circuit

STM32F103ZET6 supports PS/2 communication protocol, a mouse in PS/2 interface or a keyboard could be used. In system standby station, PS/2 data and clock lines are connected to the PA13 and PA15, the same as JTDI and JTMS two debug download port, so when using PS/2, debugging could not be used and the serial port would be an alternative . PS/2 interface circuit is shown in Figure 7.

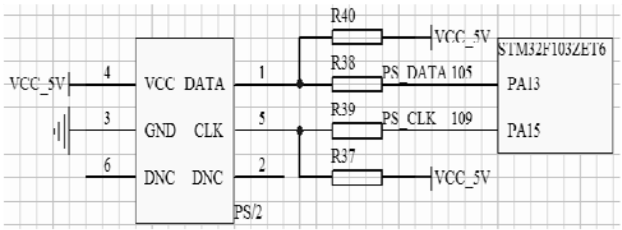

Figure 7. PS/2 Interface Circuit

3.5. SD Card Interface Circuit

STM32F103ZET6 has an SDIO interface, which can be used to expand memory through SD card, and data of control policy are inputted to NAND FLASH from a SD card before working. The calibration control platform uses 4-bits bus mode, and SDIO operating frequency is set to 18MHz. FatFs Module is adopted to create a data storage file in software implement and STM32F103ZET6 reads data from this file. SD card interface is shown in Figure 8 and Figure 9 shows a Panasonic SD card.

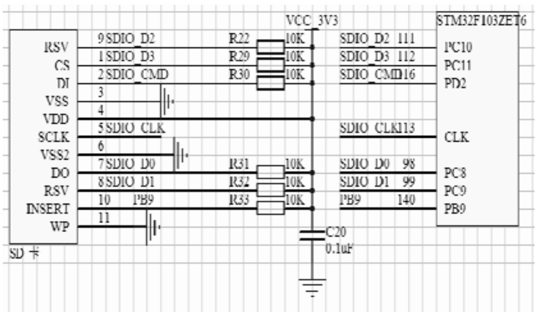

Figure 8. SD card Interface Circuit

Figure 9. Panasonic SD Card

3.6. System Power Supply Design

AC220V is used as calibration control platform's power, and DC9V is converted from an AC220V-DC9V module. DC9V is converted into +3.3V through ASM1117-3.3 as the power of STM32F103ZET6, SHT15 and MAX3232. In addition, DC9V is regulated to +5V through L7805CV as the power of TLV5636, PS/2, SD I/O, USB. And a super capacitor is used as RTC DS3231 chip's power. And +25V is produced from DC9V through MAX618 and LM2587 as the power of the 3mm band noise source. +2.5V reference voltage is for TLV5636 chip through LTC6654-2.5 and +3.3V reference voltage is for STM32F103ZET6 through LTC1164-3.3. Each part of the circuit's power supply or reference voltage is shown above.

4. Database Functional Design

In order to simulate a variety of field work environments and debug various operating parameters of a new detector with more accurate calibration, a database is created to simulate variety of environmental conditions in the system software design. This database is called control policy data. And this database is stored in the NAND Flash memory chips HY27UF082G2B. According to the definition in Table 1, two NAND FLASH HY27UF082G2BS are configured in this system and communicated with STM32F103ZET6.

Table 1. Signal Definition of NAND FLASH and FSMC

Chip Pins	I/O	FSMC Signal Name
PD11	O	CLE /A[16]
PD12	O	D[7:0]
PD/PE	I/O	NCE[x]
PD7/ PG9	O	NOE(=NRE)
PD4	O	NWE
PD5	O	INT[3:2]
PD6/PG6	I	/NWAIT

As shown in Table 1, a difference in hardware design of two memory chips is distinguished by PD7/PG9 and PD6/PG6 respectively. According to actual needs, an electronic control attenuator is controlled by the output of a DAC with the control data policy in the database.

In actual use process, 3mm band detectors could work in the different heights and different weather conditions, and the target size is several dimensions. And the database is established in three modes, called "sunny", "fog "," cloudy ".Each mode contains different heights, such as 33m, 43m, 63m, 78m, 83m, 93m, 103m, 110m and 124m, etc. and in the same height metal targets have various sizes, such as 3m*2m, 3m*3m, 3m*4m, 3m* 5m, 3m*6m and 3m*7m. Each posture has a corresponding data and is stored in the NAND Flash.

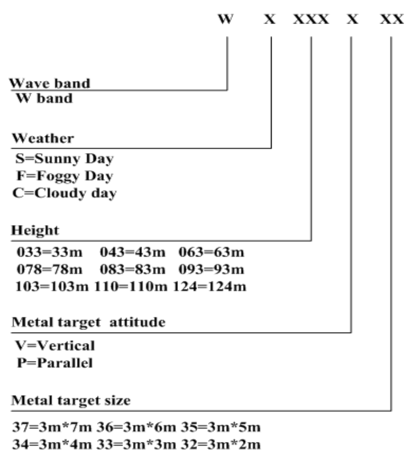

Figure 10. The naming chart of database file

The database file is named as Figure 10. Detector works in 3mm band, namely W-band. The first letter of weather conditions are divided into "sunny", "fog", "cloudy" three cases, abbreviation for S (Sunny Day), F (Foggy Day) and C (Cloudy Day).The next three numbers mean the height of detector detects, for example, 033 indicates 33m.V and P denotes the direction of the metal target placed upright (Vertical) and horizontally (Parallel). The last two numbers indicate the metal target size, for example, 37 represents 3m*7m metal targets. For example, the file name “W S 083 V 37” represents that the W band detector detects in sunny day and the height is 83m, and target is in vertical, and target size is 3*7m. Figure 10 shows the naming of radiation characteristics waveform database file.

5. Software Design

The system software flow chart is shown in Figure 11. A touch screen is used as an input. According to different AD values of the touch screen, MCU produces different responses. The software process is a "tree" structure. Firstly, MCU would initialize A/D, D/A, SDIO, RS232, real-time clock, LCD screen and other complementary devices after the system's power on. Then MCU waits for the touch screen’s interruption. When MCU receives touch screen's interruption signal, MCU inputs touch-key value and executes corresponding functions, shown as in Figure 11, such as calendar setting, data storage, target database, serial communication, data update, model output1 and model output2. Calendar setting is for setting time and date, and data storage is for saving the received data, and target database is for calling and searching the metal target database, and serial communication is for communicating with PC, and data update is for updating database, and model output1 and model output2 are the output signal models, and design of the software flow chart is brief and clear, so the system is easy for us to operate. When the system is communicated with a PC computer through RS232 interface, the data is transmitted to PC computer and PC also can control the system via serial ports .The C language programming is adopted to programmer command control and processing procedures.

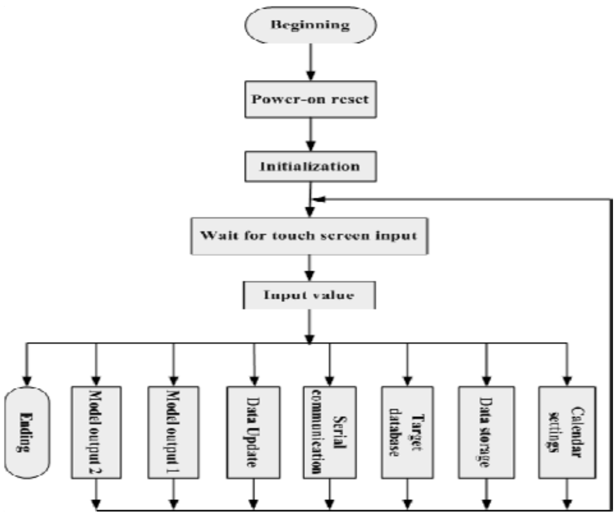

Figure 11. Software Flow Chart

6. System Debugging and Results

According to this design, a 3mm band detector is calibrated with this indoor calibration system. Figure 10 shows the circuit module of this embedded system control circuit unit, and the whole system physical is shown in Figure 11. Figure 12 shows a 3mm band detector test with this system scene and Figure 13 shows a waveform of a control policy stored in NAND flash. As is shown in Figure 13, experiment results satisfy consistency. This indoor platform system reaches practical function.

Figure 12. Embedded System Control Circuit Unit

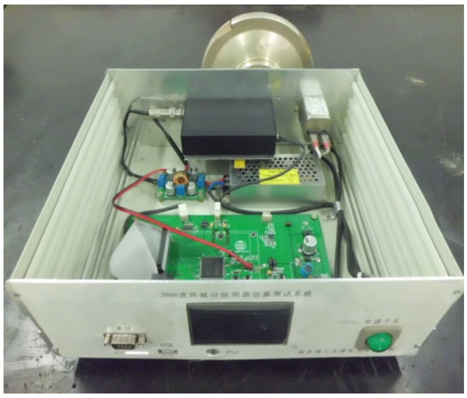

Figure 13. System Physical Picture

Figure 14. System Debugging Scene Picture

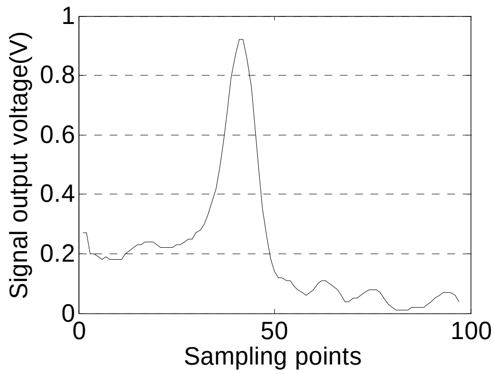

Figure 15. Control Policy Waveform

7. Conclusion

A 3mm band detector indoor calibration system is built and is used to calibrate parameters of 3mm band passive detectors onboard. This system includes a solid-state noise source, an electronic control attenuator, a STM32 and a touch-LCD screen, etc. This system is easy to operate and intuitive with rich external expansions and low power consumption. A standard metal targets radiation characteristics database is established at three different weathers, "sunny", "fog" and "cloudy", as the basis of calibration control system. And the calibration system's signal output is controlled with software, which makes the 3mm band measured passive detector output the waveforms signal similar to the metal targets signal in real environment [15, 16]. The experiment measurement results satisfy the radiation characteristics, and truly simulate the outdoor detector.

Acknowledgements

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