July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

Quality Inspection of Electronic Radio Frequency Tags Based on ARM Embedded Technology Relying on Mutual Inductance Coupling Principle

Pu Yan*

College of Technology and Engineering, LUT, Lanzhou 730000, China

Article Info
Volume 83
Page Number: 5843 - 5850
Publication Issue:
July - August 2020

Article History
Article Received: *25 April 2020*
Revised: *29 May 2020*
Accepted: *20 June 2020*
Publication: *28 August 2020*

Abstract

To detect electronic tags with high efficiency and accuracy, we propose a new type of automatic detection equipment for electronic tags based on the principle of mutual inductance coupling in this paper. In the design and implementation of the electronic label quality inspection system, the system is applied to the quality inspection link of electronic label production. The system implements accurate measurement of electronic tag quality parameters by DDS frequency synthesis technology, FIFO data buffer structure, and digital signal processing technology based on the ARM embedded hardware platform according to the principle of mutual inductance coupling. Meanwhile, the system is debugged through embedded software to achieve the automation of label quality parameter detection in the production process. Through experimental testing and field operation demonstration, the system has high detection accuracy, robust and reliable operation.

Keywords: *Electronic Tag, Automatic Detection System, ARM Embedded Technology, Principle of Mutual Inductance Coupling;*

Introduction

With the development of the economy and the improvement of people's living standards, the concept of shopping is no longer a simple sale of commodities for people. More and more attention has been paid to the shopping environment and shopping experience. The open-shelf shopping model comes into being at the requirements of the times [1-2]. However, while the service quality and economic benefits of merchants are improving, the introduction of open-shelf shopping mode has also brought a severe problem: theft of goods [3-4]. According to the statistical results of the relevant commercial departments, in recent years, the domestic retail industry has suffered economic losses up to 10 billion yuan each year, in which 5% to 8% of the losses are caused by the theft of open-shelf commodities. Hence, to solve this problem, Electronic Article Surveillance (hereinafter referred to as EAS for short) has become the choice of most businesses [5-6]. In plain terms, EAS is a type of commodity self-defense device. It can actively detect whether a commodity has left the designated area without authorization [7-8]. Once it detects that someone attempts to take an item without payment, it will issue an alarm so that the thieves have no place to hide. It has undoubtedly fundamentally changed the state of passive anti-theft monitoring in the past and made anti-theft measures more comprehensive and reliable [9-10].

The electronic anti-theft system for commodities is mainly composed of three parts: the electronic tags, the sensors, and the deactivator, in which the electronic tag is the main core. As an essential part of the anti-theft system, the application and demand of electronic tags in various industries have gradually increased. According to statistics, in recent years, the domestic demand for electronic tags has

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

grown rapidly at a rate of 45% to 50% per year. The increase in the use of electronic tags has directly contributed to the sharp rise in the production of electronic tags. However, the technology of detecting the quality of electronic tags is always the bottleneck in system development. Hence, a reliable and efficient test system that can accomplish the accurate and stable detection of the specific parameters of electronic tags is urgently needed in the market.

1. Hardware Architecture of the System and Selection of the Main Chip

The electronic tag automatic detection system designed and developed based on the ARM embedded technology studied in this paper is composed of a master control circuit, a signal generator, a signal acquisition module, a storage module, and a human-machine interface (HMI) control circuit module. The system block diagram is shown in Figure 1 as the following. Its working principle is that the frequency sweep signal source of the detection device is used to generate a specific excitation signal frequency, which is radiated through the antenna coil. If the electronic tags appear in the radiation area of the antenna coil, the antenna and the detection tag will be coupled, which is detected by the detection circuit and sent to the system for the corresponding processing.

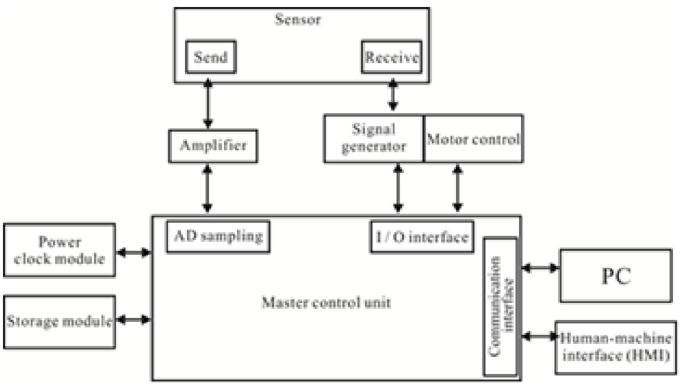

Figure 1. System block diagram

1.1. Core Processor

The system not only needs to complete a large number of numerical operations but is also required to interact with multiple external devices. Hence, the system processor should not only have a high response speed, fast digital signal processing operation but also needs to have rich control interfaces and abundant external interface resources.

In the control chip of the design, the LPC2214 microprocessor of NXP company based on the ARM7 series ARM7TDMI-S core is selected. In the microprocessor, the 256KB high-speed Flash memory and 16KB SRAM on-chip are integrated with 112 general I / O interfaces and 12 external interrupts, including two 16C550 UART serial ports according to the industry standard, two high-speed I2C buses (400kbit / s), SPI and SSP with buffering function and variable data length. The processor can implement in-system programming / in-application programming (ISP / IAP) through the on-chip boot loader and complete the data acquisition and processing. The maximum 60MHz CPU operating frequency can be achieved through the on-chip PLL (100us setting time). For applications with strict code size control, its high-density 16-bit Thumb instruction set mode can reduce the code size by more than 30%, but the performance loss is very small. In short, the processor has the characteristics of high performance and low power consumption. Based on the principle of reduced instruction set computer (RISC) design, it has excellent throughput and real-time interrupt response capability.

1.2. Detection Signal Generator

In order to meet the requirements of the frequency-scanning signal source of the detection system and generate a specific frequency excitation signal, at the same time, to facilitate the system construction, improve the signal stability, and reduce the number of components, we adopt the AD9830 DDS chip by AD company as the frequency synthesis device. The chip is produced based on the direct digital frequency synthesis technology, which

Published by: The Mattingley Publishing Co., Inc.

TEST Engineering & Management

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

has integrated a phase accumulator, a sine look-up table, and a 10-bit digital-to-analog converter internally. It has two modulation capabilities: the phase modulation and the frequency modulation, so that it can support up to 50MHz clock rate, and the frequency control precision can reach one in four billion. It has a maximum output voltage of 1V and a maximum output current of 20mA. Hence, the maximum output power is only 20mW. In order to ensure that the swept signal has sufficient energy to cause the oscillation of the electronic tags, it is necessary to amplify the power of the AD9830 and improve the signal emission power.

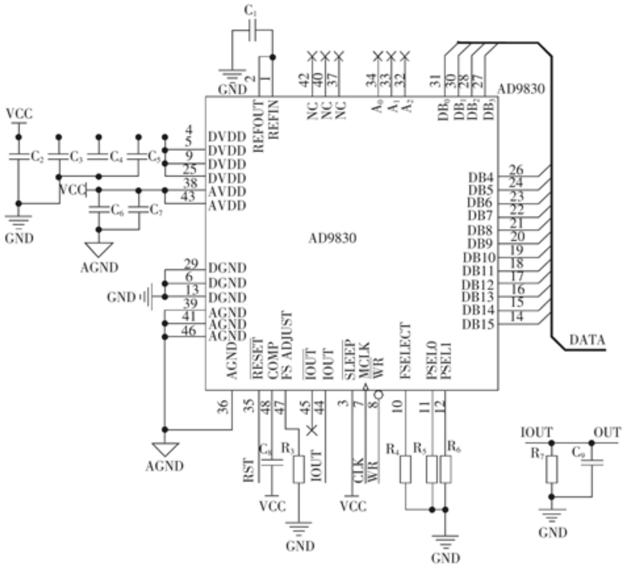

Figure 2 Interface circuit of the signal generator

1.3. Acquisition Module for the Detection Signal

In order to acquire the amplitude-frequency characteristic curve of the electronic tags, the signal acquisition module needs to perform sampling on the response of each discrete frequency point in a frequency sweep period. As the LPC2214 comes with a 10-bit A / D conversion function, no external A / D converter is required. However, the signal output by the sensor receiving coil is relatively weak, and the feedback signal of the electronic tag received by the system is also relatively weak. Hence, it is necessary to amplify the signal before connecting it to the chip pin. In the system, a two-stage amplifier circuit is adopted. At the same time, a DC bias voltage is introduced to avoid circuit distortion. The two-stage amplifier circuit is shown in Figure 3 above.

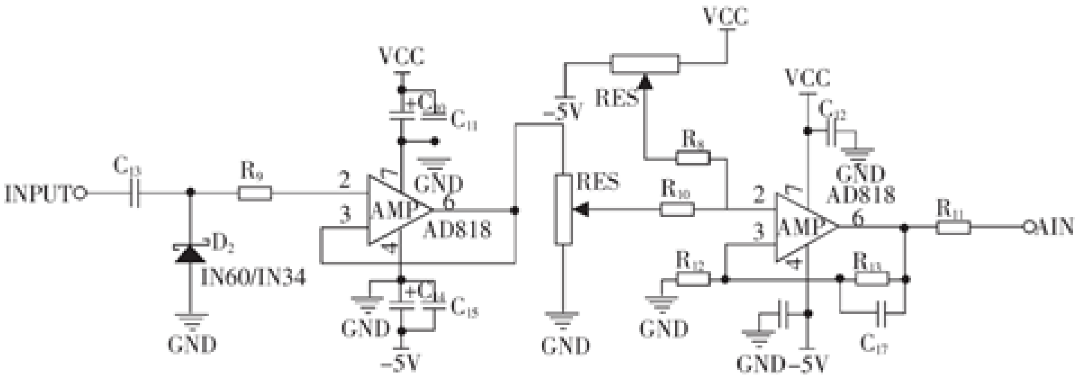

Figure 3 Amplifying circuit

1.4. I / O Control Interface Module

The setting of the system control interface is mainly to implement the online automatic detection function of the electronic tag detection device and the signal control execution unit, which includes the trigger of the sorting system and the control of the soft tag motor. The module is driven by the control signal of the processor I / O port. Due to the limited

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

driving force of the control signal processor GPIO, and in order to ensure the purity of the system in a harsh environment and the stability of the external control signal, we adopt the photoelectric coupling method in the design of the circuit, where the optical signal is used as a medium to implement the coupling and transmission of electrical signals effectively. At the same time, it can also suppress the interference and amplify the output voltage, which has significantly improved the driving capacity of the control signals.

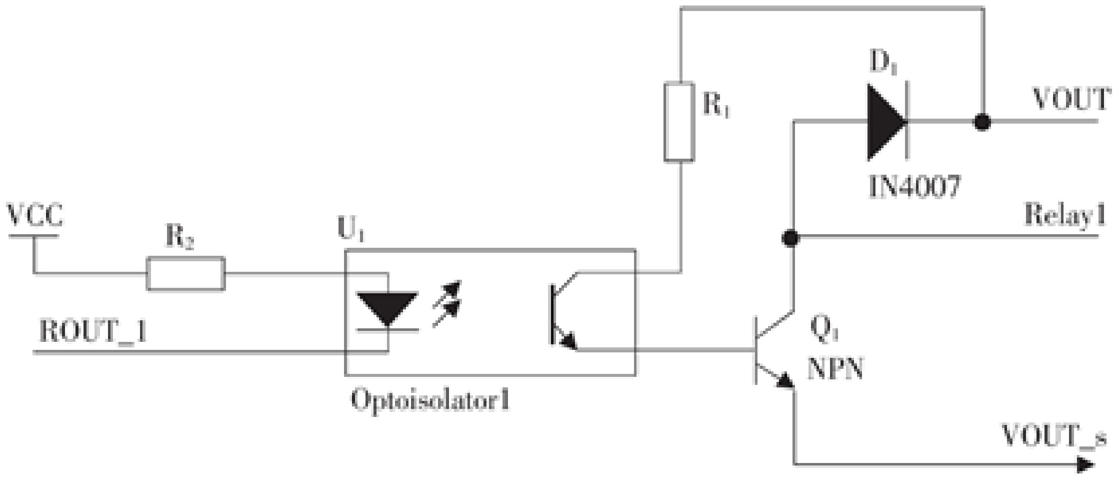

Figure 4. Drive circuit

In order to implement the capacity of the electronic tag detection system to communicate with the external network, we have also designed a communication interface module in this paper. System communication is mainly to implement the data transmission between the core processor and the man-machine interface controller, as well as the data communication between the core processor and the PC. LPC2214 comes with two standard UART interfaces, which can be easily extended.

2. System Software Design

For embedded system equipment, if the hardware structure of the system is the backbone of the system, then the embedded software is the soul of the system equipment. As the core of the system, the embedded software is a set of programs based on the embedded hardware structure. The software drives and controls the equipment to work, run, and process the related data, thereby implementing the functional design and realization of the embedded system.

In the electronic tag detection equipment software system designed in this paper, the ADS1.2 integrated software development environment and μC / OS-II operating system are adopted. The operating system can meet the requirements for the multi-task working mode and has the characteristics of high execution efficiency and robust scalability. According to the analysis of the functional requirements for the system, this equipment needs to implement multiple functions such as tag detection, data storage, data communication, and assembly testing. Hence, the modular design method is applied to carry out procedure analysis and planning of the system.

2.1. Software Design of the Device Driver Layer

The device driver software designed in this paper mainly includes an AD sampling driver, a DDS frequency sweep driver, an I2C memory chip driver, a flash driver, an RTC real-time clock driver, a peripheral control driver, a human-computer interactive communication driver, and so on. In

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

general, each hardware equipment driver model includes three parts as the following: Module initialization, interrupt service program, interface configuration (API), and the operation flow chart is shown in Figure 5 as the following.

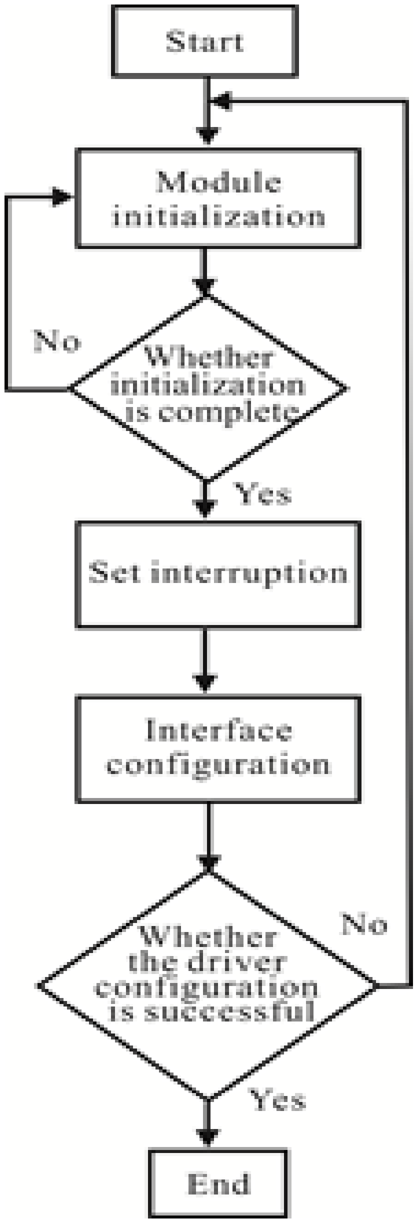

Figure 5. Flow chart of the driver layer

2.2. Software Design of the Device Function Module

The main design task of the system is to implement the detection of electronic tags and to complete the measurement process for the quality parameters of a single electronic tag under the triggering condition quickly and effectively. When the electronic tag enters the detection area, the system starts to work, which is initiated by the signal volume notification of the detection task. Subsequently, the signal generation function and information collection interface function in the driver layer and function module layer is called to complete the frequency sweep output and the collection of the detection signal information at the reception terminal. Then, the system calls the data processing module to filter the collected received signal, calculate the tag quality parameters, and finally determine whether the electronic tag is qualified based on the parameters.

The communication tasks of the man-machine interactive interface and the data transmission tasks of the PC are mainly responsible for receiving instructions, and their implementation methods are basically the same. When the reception of the data generated in the test is interrupted, the execution task is activated. In addition, the instruction protocol acceptance qualification for the received data is determined in the task to ensure that the data communication can be accomplished. It should be specifically pointed out herein that in all tasks, the priority of the electronic tag discrimination response task and the communication task of the human-computer interaction interface is the highest. This is because only the efficient identification of the quality of the electronic tags and the rapid implementation of the control commands of the response device can ensure that the system achieves the highest real-time performance, thereby enhancing the competitiveness and production efficiency of the enterprises. The flow chart of the primary detection task of the system is shown in Figure 6 above.

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

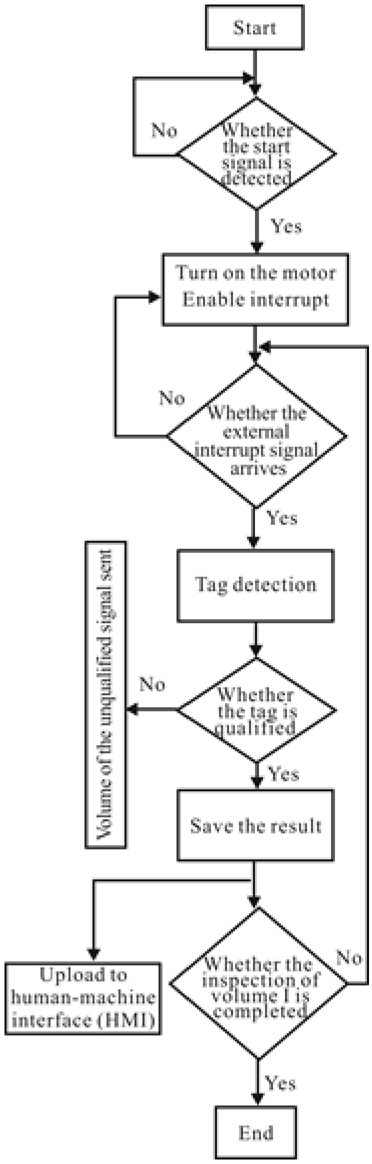

Figure 6. Flow chart of the main detection task of the system

3. Testing of the Automatic Test System

After the hardware circuit construction and software code writing and design are completed, in order to verify whether this electronic tag detection system can truly implement the automatic detection task, we will conduct an actual measurement on its performance and stability.

In the test, we use an electronic tag with a center frequency of 8.2 MHz as the experimental object, and this tag is a hard tag. Figure 7 shows the physical diagram of the hard tag produced by the manufacturer, (a) is an open air coil, (b) is a finished product. From the figure, it can be seen that such tags have a special shape. Hence, so we adopt the lateral detection method.

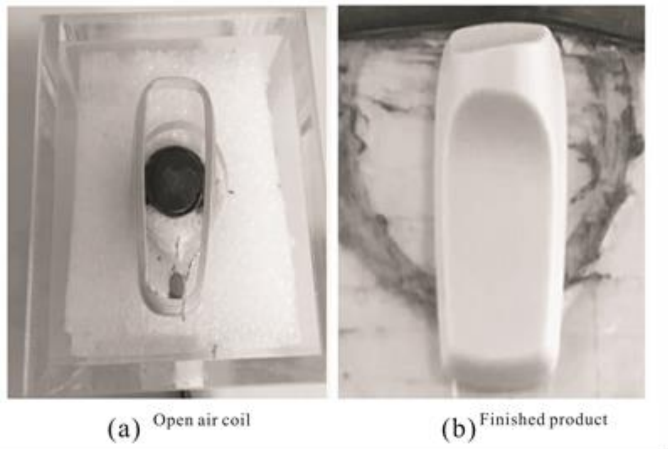

Figure 7. Physical diagram of the electronic tag

In order to detect the accuracy and stability of the system function, we selected 30 electronic tags as the detection object in this test. Firstly, they were tested in the case of open air coils, respectively. Subsequently, they were made the finished products by the manufacturer, and the finished products were tested under the same testing conditions successively. The test result corresponding to each product is shown in Table 1 as the following.

Table 1 Comparison table of test parameters for the open air coil and finished products

No.	Open air coil			Finished goods		
	Freq 7.833~8.486	Q ≥130	P-P	Freq 7.872~8.528	Q ≥85	P-P
1	8.16	139.8	0.613	8.19	96.7	0.419
2	8.06	139.1	0.614	8.20	99.6	0.414
3	8.16	138.4	0.613	8.27	100.6	0.427
4	8.15	135.5	0.578	8.28	97.9	0.422
5	8.22	137.1	0.605	8.13	100.7	0.428
6	8.18	137.0	0.606	8.27	100.6	0.414
7	8.09	133.3	0.605	8.08	97.6	0.422
8	8.18	138.	0.62	8.18	105.	0.44

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

		0	5		4	1
9	8.17	136.8	0.609	8.19	101.9	0.427
10	8.20	135.6	0.599	8.34	104.1	0.425
11	8.05	137.9	0.628	8.24	100.4	0.426
12	8.13	139.3	0.619	8.23	102.7	0.433
13	8.15	139.2	0.610	8.29	103.6	0.443
14	8.04	134.3	0.569	8.27	104.5	0.450
15	8.05	137.3	0.605	8.35	102.2	0.418
16	8.10	135.8	0.597	8.15	98.7	0.408
17	8.02	132.2	0.593	8.09	103.6	0.438
18	8.12	139.0	0.615	8.22	100.7	0.428
19	8.15	131.5	0.589	8.25	102.7	0.425
20	8.12	139.0	0.603	8.32	99.9	0.425
21	8.13	134.5	0.581	8.22	98.1	0.417
22	8.22	139.0	0.584	8.38	102.5	0.437
23	8.15	136.4	0.610	8.38	105.1	0.440
24	8.10	139.0	0.609	8.24	100.8	0.429
25	8.04	133.4	0.609	8.12	105.1	0.447
26	8.07	132.5	0.599	8.19	99.4	0.433
27	8.02	138.0	0.619	8.24	102.3	0.444
28	8.11	136.2	0.590	8.30	97.2	0.426
29	8.23	138.7	0.587	8.19	99.3	0.427
30	8.17	137.6	0.624	8.20	102.6	0.438

In Table 1, Freq stands for the center frequency, which is a core parameter index of the electronic tag. When the open air coil is specified, the center frequency range of the product is (7.833 ~ 8.486) MHz; while after it is made into a finished product, the center frequency range of the product is (7.872 ~ 8.528) MHz. Q stands for the quality factor, which is a standard to measure the quality of the tag. For the same type of tag, the higher the Q value is, the better the quality is. The P-P value reflects the amplitude of the waveform reflected on the sensor; the higher the P-P value is, the more sensitive the system alarm response is. According to the test results, these 30 samples are all qualified products when they are open air coils and made into finished products. In addition, and the trend of changes in the parameter index of Q value and P-P value is obviously consistent, which is completely in line with the actual situation of electronic tags. Hence, the automatic detection system proposed in this paper can meet the detection requirements of tag manufacturers in the aspects of functional design, measurement accuracy, and operational stability, and has certain practical value.

4. Conclusions

In this paper, a type of automatic detection device for RFID electronic tags based on the ARM embedded technology is studied. This device can not only determine whether the RFID electronic tags are qualified but also accurately output the specific parameters of the tags, which has significantly improved the competitiveness and production efficiency of the enterprise, with a certain practical value.

References

1. Kaka Ma, Feng Tang, & Julie M. Schoenung. (2010). Korean radio-frequency identification technology gets international approval.(electronics). acta materialia, 58(5), 1518-1529..
2. Ji, W. , Weiying, S. , Jianhua, Z. , Cheng, Z. , Hao, L. , & Jingye, Y. , et al. (2011). Imaging interplanetary cmes at radio frequency from

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5843 - 5850

solar polar orbit. Advances in space research, 48(5), 943-954.

3. Liu, Q. , Le, T. , He, S. , & Tentzeris, M. M. . (2016). Button-shaped radio-frequency identification tag combining three-dimensional and inkjet printing technologies. IET Microwaves, Antennas & Propagation, 10(7), 737-741.
4. Sakalli, E. , Baylancicek, S. , Yuksel, M. , Erdurak, S. C. , & Dadas, B. . (2013). Levels of reactive oxygen species in rat tympanic membranes after incisional versus radiofrequency myringotomy. International Journal of Pediatric Otorhinolaryngology, 77(5), 792-795..
5. Rossner, M. . (2012). Radiofrequency ablation and endoscopic resection in a single session for barrett's esophagus containing early neoplasia: a feasibility study. Endoscopy, 44(12), 1096-1104..
6. Raman M R G , Somu N , Kirthivasan K , et al. An efficient intrusion detection system based on hypergraph - Genetic algorithm for parameter optimization and feature selection in support vector machine[J]. Knowledge-Based Systems, 2017, 134(oct.15):1-12..
7. Kersten, J. T. , & Fethke, N. B. . (2019). Radio frequency identification to measure the duration of machine-paced assembly tasks: agreement with self-reported task duration and application in variance components analyses of upper arm postures and movements recorded over multiple days. Applied Ergonomics, 75, 74-82..
8. Filby, A. , Taylor, M. , Lipman, G. , & Haidry, R. . (2016). Ptu-142?a cost-effectiveness analysis for radiofrequency ablation (rfa) in the treatment of patients with barrett's oeosphagus related neoplasia in the united kingdom. Gut, 65(Suppl 1), 127.2-128..
9. Sánchez, Daniela, Melin P , Castillo O . Optimization of modular granular neural networks using a hierarchical genetic algorithm based on the database complexity applied to human recognition[J]. Information Sciences, 2015, 309:73-101.
10. Tsimafeyeu I, Chung B, & Zart JS. (2012). The effect of cytoreductive radiofrequency ablation (crfa) on results of therapy with sunitinib or interferon-alpha (ifn) in metastatic renal cell carcinoma (rcc) patients with a small primary tumor. journal of clinical oncology, 13(13), 76-86.

Published by: The Mattingley Publishing Co., Inc.