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Radio-Frequency Data Transmission for Remote-Controlled Mechatronic Systems

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Introduction

In many mechatronic systems, especially in mobile applications, there is some information data that has to be transferred between different modules. Wireless transfer is a very convenient way even in non-portable equipment, and it is a must for mobile systems. Besides the infrared devices, RF (radio-frequency) transmission is one of the best suited. The benefits of RF transmission are mainly in its better range and high reliability.

In case that the amount of data to be transferred is not very high and the range is below 80–100 m, several very simple decisions exist. Choosing the proper application leads to lowering the system cost while maintaining required parameters and reliability of the system. Some possible decisions are discussed below.

Superregenerative (SR) Receivers

In most radio applications, the receiver is selectivity-limited. In other words, the minimum signal recoverable by the receiver is limited not by the thermal noise of the receiver (which sets the receiver "sensitivity"), but other "noise" located in the "ether", for example from other transmitters, like FM radio stations.

Until recently, the simplest and most cost-effective UHF radio receiver for wireless remote-control applications was the SR receiver. SR have an RF bandwidth of several MHz, and demonstrate a typical range of about 100 m. SR receivers are elegant in their simplicity, but analytically difficult to understand due to their inherent nonlinearity. Development and optimization of these receivers is generally an empirical process.

SR receivers have several important advantages:

• No local oscillator (LO), with its associated complexity
• Wide RF bandwidth allows operation with LC transmitters
• Easily tuned to any frequency of choice
• Readily designed for low power (e.g., battery) operation

On the other hand SR receivers exhibit a number of drawbacks, limiting their application and ease-of-use, namely:

• Reradiate RF noise (called "regenerative noise")
• Require manual frequency tuning
• "Regenerative noise" crosstalk limits how closely SR receivers can be collocated
• Require managing an extensive bill-of-materials of discrete components
• Cannot easily take advantage of IC integration

Superheterodyne (SH) Receivers

SH receivers outperform SR receivers mainly because

- SH is more analytically understandable
- selectivity improvements can improve the range performance
- SH circuits can be integrated into an IC
- SH receivers can be easily electronically tuned

Still, the lowest cost solution has traditionally been the SR, especially where the user is willing to manually tune the receive frequency. While SH selectivity, and hence range, can be improved, this improvement comes at a sizable cost. Specifically, the LO (local oscillator) must be very accurate, and for this reason is generally derived from either a crystal or SAW resonator. Such devices are far more expensive than LC tank circuits. Further, the high receiver LO accuracy also requires that the transmit frequency be highly accurate. So here again, the transmitter frequency must be crystal or SAW resonator-based. LC-based transmitters simply will not do! The one manufacturing advantage to SH receivers is the fact that the receivers and transmitters do not require tuning of the transmit and receive frequencies, due to their requirement for accurate resonators. An additional advantage is that the demodulator can be integrated along with the down converter to help lower costs.

Disadvantages include:

- LO re-radiation back through the antenna, which can be minimized through IC integration
- operating frequency is difficult and costly to customize.

Integrated solutions – differences from standard SH receivers.

If one should list the best features of both the SR and SH receiver that should be incorporated into a new receiver, the list would be:

• No manual tuning of the receiver
• Compatible with both LC and SAW/crystal transmitters, without modification
• No expensive crystals, SAWs, or coils required
• Operating frequency is easily customized
• No SR “regenerative” noise to reradiate
• Integration to minimize LO reradiation to within regulatory limits
• Integrated demodulator to lower costs
• A very small bill-of-materials to manage
• Cost/range comparable to SR receiver
• Simple, parasitic insensitive layout

All of these features incorporated into the MICRF001, yield a receiver that is simple to apply, easy and inexpensive to manufacture, and requires no manual tuning whatsoever.

It employs the basic SH down-conversion approach without the accuracy requirements generally imposed. All that is required is to attach a ceramic resonator to the MICRF001, in the range 2.0 MHz to 3.5 MHz, based on the desired system transmit frequency. Ceramic resonators are significantly less expensive than crystal or SAW resonators, and are easily and inexpensively customized to any frequency of choice. The remaining features are accommodated by completely integrating all functions of the receiver on an IC, including the demodulator. Demodulator bandwidth is programmable in four discrete values, which gives designers sufficient flexibility without complicating the development process. Finally, if the user chooses, the MICRF001 can be easily converted to a standard SH receiver, where the ceramic resonator would then be replaced with a crystal. In this application, the transmitter frequency must also exhibit the same crystal or SAW-resonator accuracy.

MICRF001 theory of operation

The block diagram in Fig. 1 illustrates the basic structure of the MICRF001. Identified in the figure are the three principal functional blocks of the IC:

- SH UHF down converter,
- OOK demodulator,
- reference and control.

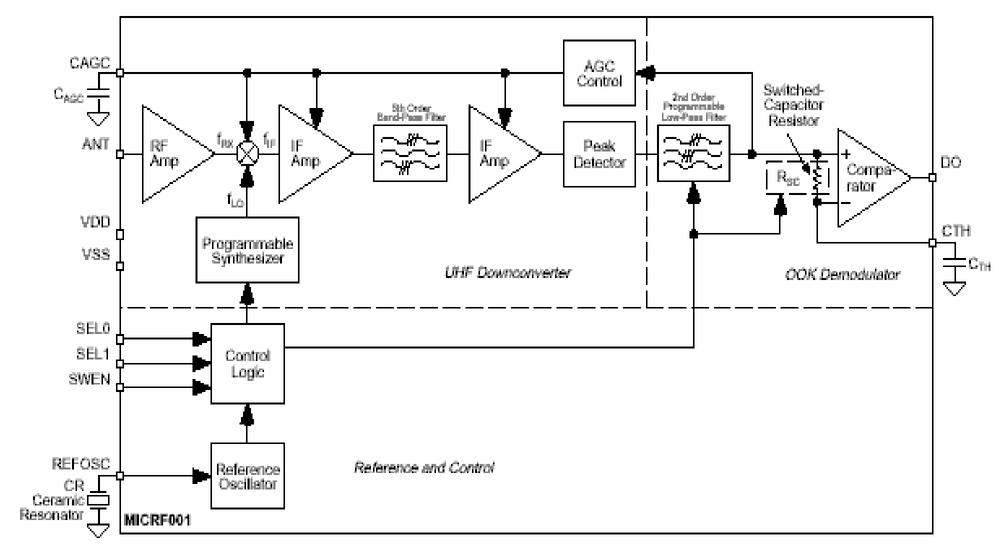

Fig.1. MICRF001 – block-diagram

Also shown in the figure are two capacitors (C_{TH} , C_{AGC}) and one timing component (CR), usually a ceramic resonator. With the exception of a supply decoupling capacitor, these are all the external components needed with the MICRF001 to construct a complete UHF receiver. An example of sweep operation would be where the MICRF001 must operate with LC-based transmitters, whose transmit frequency may vary as much as ±0.5% over initial tolerance, aging, and temperature. In this mode, the LO frequency is varied in a prescribed fashion which results in down conversion of all signals in a band from 2% to 3% around the transmit frequency. A range penalty will occur in installations where there exists a competing signal of sufficient strength in this small frequency band of several percents. (This penalty also exists with SR type receivers, as their RF bandwidth is also generally from 2% to 3%. So any application for an SR receiver is also an application for the MICRF001.)

TRF6900 – Single Chip RF Transceiver

Key Features

TRF6900 single-chip UHF transceiver:

• 850 – 950 MHz operating range.

• FSK operating mode.

• Low power consumption due to ultra-fast turn-off / turn-on times.

• On-chip DDS synthesizer, VCO and reference oscillator enables channelized systems.

TRF6900 Single-Chip Transceiver

The TRF6900 is a single-chip 850-950 MHz UHF transceiver with operating modes including Frequency Shift Keying (FSK) and narrow-band FM along with integrated features such as a Direct Digital Synthesizer (DDS), Voltage Controlled Oscillator (VCO), and data slicer. A transmit power amplifier is integrated as well to provide the needed output power. The TRF6900 is designed for low power operation, ensuring long battery life for in-field applications such as utility metering equipment. Designers can program the MSP430 to selectively turn on or off each major functional block. In addition, the transceiver features ultra-fast system turn-on and turn-off times in order to keep battery drain at a minimum. The TRF6900 consumes typically 2 μA in standby mode and operates from 2.2 V to 3.6 V power supply. By keeping the external component count low, the single-chip integration makes it possible to reduce the system complexity and cost. For systems that do not require a microcontroller, the TRF6900 can be used as a stand-alone device.

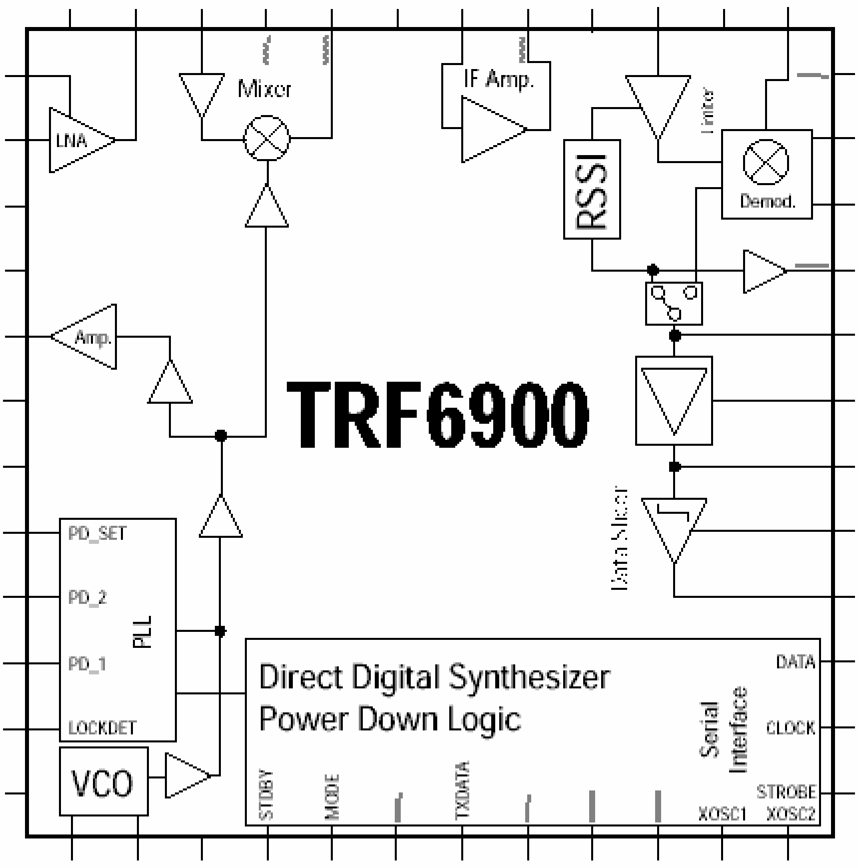

Fig.2. TRF6900 – block-diagram

TRF6900 key advantages for application:

• High performance system offering a bidirectional RF data link in a reliable frequency band.

• FSK modulation mode possible.

• Single-chip transceiver integration lowers the total system cost, increases reliability and simplifies design.

• Integrated VCO's and power amplifier.

• Data rates up to 200 Kbits per 1 s.

• On-chip Direct Digital Synthesizer provides precision frequency control and fast channel hopping (spread spectrum).

• Ultra-fast system turn-on and turn-off times offer a quick response time and low power consumption as the device can remain longer in standby mode.

• No adjustment points which lowers production costs.

The TRF6900 is designed for simplified implementation, so even designers who don't have extensive RF design experience can easily use it to build RF into their next system design. In addition, the low external component count of the TRF6900 and no required adjustment points reduce the production cost even further.

The TRF6900/MSP430 chipset solution. TRF6900 is very well suited for use in combination with the MSP430 ultra-low-power microcontroller. TRF6900/MSP430 chipset provide the following benefits:

• Operation in the reliable 850–950 MHz ISM (Instrumentation, Scientific & Medical) bands.

• Easy-to-use because of high integration resulting in low external component count.

• Total system solution for low system cost.

• Low power consumption for longer battery life.

• Fully programmable operating modes and frequency control.

Design support materials include a TRF6900/MSP430 Evaluation Kit, schematics, S/W utilities, MSP430 S/W routines and examples to program the TRF6900 to setup a complete RF link, datasheets and application notes.

Ultra-Low-Power Microcontroller Family MSP430. The MSP430 generation of microcontrollers provides very high ratio of ultra-low-power operation and high performance. The devices feature a 16-bit RISC core with up to five million instructions per second (MIPS), which is much more powerful than standard 4- and 8-bit microcontrollers. The devices complement this high performance with ultra-low power consumption of 350 μA in active mode, 1.3 μA in standby mode, 0.1 μA in shutdown mode, and a very fast 6 μs wake-up time. MSP430 devices control all of the settings of the RF device through a simple universal digital interface and can process and generate the received or transmitted data. The MSP430 can switch the TRF6900 into standby/shutdown mode to reduce power consumption, while consuming virtually no power of its own. In addition to this core performance, devices in the family are available with a range of integrated peripheral options, including a 14-bit analog to digital converter (ADC), liquid crystal display (LCD) driver, universal synchronous asynchronous receiver transmitter (USART) and several different timer configurations.

Comparison between MICRF001 and TRF6900. TRF6900 is a complete transceiver (transmitter and receiver) integrated in a single chip, while MICRF001 is completely compatible with either SAW-based or LC transmitters, but it's only a receiver and needs a separate transmitter. MICRF001 is intended for use in the UHF frequency band from 300 MHz to 440 MHz while TRF6900 operates in the more reliable 850–950 MHz ISM (Instrumentation, Scientific, & Medical) bands. TRF6900 has lower power consumption and its operating modes and frequency control are fully programmable. The frequency of the MICRF001 is also programmable, but by means of choosing the appropriate crystal frequency. So, we can come to a conclusion that the TRF6900 is more sophisticated solution, but while the MICRF001 is still cheaper, in many applications it could be used with success.

References

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Радиочастотная передача данных для цели дистанционного управления мехатронных систем

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(Р е з ю м е)

Цель настоящей работы представить основные характеристики радиочастотных приемников и передатчиков, предназначенных для передачи данных при дистанционном управлении мехатронных систем. Показаны преимущества и недостатки разных методов и средств, которые надо учитывать при выборе элементов.

Интегрированый чип передатчика уменьшает сложность и стоимость реализации, увеличивает надежность и минимизирует время настройки.