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TIRIS™

APPLICATION NOTE

RF Module with IC RI45538

REV. 2.0
12/12/94

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Contents

Rev. 1.0 - 05/24/94
Rev. 1.1 - 05/30/94
Rev. 2.0 - 12/12/94 - "Circuit with Tapped Antenna Coil" starting from page 17 added.

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The TIRIS RF Module generates RF emissions at 134.2 kHz. The radiation of the fundamental and the harmonics will vary with the type of antenna and other devices or functions connected to the RF module.

Prior to operating the TIRIS RF Module with antenna(s), power supply and a control module or other devices, the required FCC or PTT approvals must be obtained.

Sale, lease or operation in other countries may be subject to prior approval by the government or other organizations.

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The TIRIS RF Module product is considered by the Federal Communications Commission (FCC) to be a "subassembly". As such, no prior approval is required to import, sell or otherwise market the RF Module in the United States. In order to form a functioning radio frequency RF device, the RF Module must be connected to a suitable antenna, power supply, and control circuitry. **A radio frequency device <u>may not</u> be operated unless authorized by the FCC nor may a radio frequency device be marketed (i.e. sold, leased, imported, or advertised for sale or lease) without the prior grant of an FCC equipment authorization.**

FCC authorization to operate an RF device may take one of two forms: first, the FCC may grant the user an experimental license; second, the FCC may issue an equipment authorization permitting use of the RF device on an unlicensed basis. TI can assist the user in obtaining an experimental license that will cover a specific installation of the RF Module in a specific site or sites. Experimental authorizations are appropriate to cover operations during the development of an RF device. A grant of equipment authorization (known as "certification") must be obtained from the FCC before RF devices are marketed or operated on a nondevelopment basis.

An equipment authorization has already been issued for use of the RF Module and other TIRIS equipment (including antennas) in certain configurations. This authorization does not cover all possible combinations of equipment and, in particular, covers only specific antenna configurations. Should a user desire to use the RF Module in a configuration not yet approved, TI can assist that customer to obtain the necessary equipment approval.

Please contact Texas Instruments, if you would like our assistance on these issues.

PURPOSE

This application note shows three circuit proposals for a TIRIS RF Module using the IC RI45538. Depending on the actual antenna size, the examples show RF Module circuits for reading ranges up to about 10 cm. For higher reading ranges an additional amplifier can be used. In case high Q antennas are used to improve the reading/writing range, an antenna damping circuit will be required.

REFERENCE

[1] Data Sheet TIRIS RF Module IC RI45538, Rev. 1.4
[2] RF Module Sequence Control Specification, Rev. 2.2 - 07/08/93 (classified)
[3] Antenna Reference Guide, First Edition - January 1992

INTRODUCTION TO TIRIS

A TIRIS RF Module is the interface between the TIRIS transponder and the data processing unit of a TIRIS Reading/Writing System. It has the capability to charge up a TIRIS transponder, to write a read/write or multipage one, to receive the transponder signal and to demodulate it for further digital decoding.

INTRODUCTION TO RF MODULE IC RI45538

General

The RFM IC RI45538 is built with a CMOS process and contains almost every active element needed for a TIRIS RF Module. Not included is the normally needed power stage to charge the transponder over longer distance.

The transmitter logic generates the transmitter frequency by dividing the crystal-controlled oscillator frequency by 128. The transmitter logic controls a high side and a low side driver which allow to use different types of power stages including push / pull stages with logic level MOSFETs.

The transmitter control signal TXCT- activates the transmitter driver outputs as long as it is "low". In receive mode when TXCT- is "high" the driver output TXHI is active "high" while the driver output TXLO is "open".

The transmitter power control signal TPC controls the intensity of the transmitter charge pulse by changing the duty cycle. The power is reduced if the TPC input is "low". Both, TXCT- and TPC are Schmitt-Trigger inputs and have internal pull-up sources.

To amplify the antenna signal, three CMOS inverter stages A1, A2 and A3 are available. The output of A3 is internally connected to the input of the digital demodulator.

The digital demodulator separates the keyed frequencies (FSK) of the transponder by using the reference oscillator and generates the receiver data signal RXDT- and the receiver clock signal RXCK. Unlike other methods this circuit neither needs alignment nor additional external components.

Timing between the Signals RXDT- and RXCK

The NRZ data stream of RXDT- contains the identification data, the protection data and the framing bits. The clock signal RXCK is used as time reference for the data stream RXDT-. Figure 1 shows the timing of these two signals, which differs from [2] and other TIRIS RF Modules where the positive edge of the RXCK signal is placed in the center of the data bit. Because the absolute timing for these signals is not given by the RFM IC but by the transponder, Table 1 list the minimum times for a transponder which tends with his tolerances to higher frequencies. Shifting the positive edge of RXCK more to the begin of the data bit gives a µController more time to detect the data bit.

Another item which differs to [2] is the inverted polarity of the signal RXDT-. This means if RXDT- is "low" data bit value is "1".

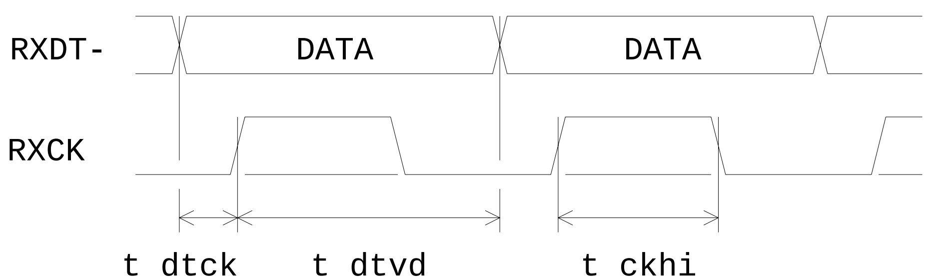

Figure 1: Timing Diagram for the Signals RXDT- and RXCK

Table 1: Timing characteristics between the Signals RXDT- to RXCK

Reference	Description	Value	Unit
t_dtck	Delay time from begin of data bit at RXDT- to positive edge of RXCK	min. 20	µs
t_dtvd	Time for data bit of RXDT- is valid after positive edge of RXCK	min. 90	µs
t_ckhi	Time for clock signal RXCK is high	min. 55	µs

CIRCUIT DESCRIPTIONS

General

The described circuits are suited to read all types of TIRIS transponder and to write the programmable ones including multipage. Due to the wide temperature range of the ASIC RI45538 and by using appropriate components, all circuits can work over an ambient temperature range of -40 to +85 °C. Beside several applications they can also be used in the automotive area.

The circuit uses a single supply voltages for the IC and the transmitter power stage. The capacitor C4 between the VSP and GND pins is necessary to reduce the RF ripple voltage and EMI on the supply line during the transmit mode. Therefore it must have low impedance at the transmit frequency of 134.2 kHz. Because the built-in amplifiers and the logic uses the same supply lines, the low impedance for the capacitor C4 is also needed during receive mode to reduce the supply noise produced by the internal high speed logic.

The built-in oscillator of the ASIC RI45538 operates with the crystal in parallel resonance mode. The size of the capacitors C5 and C6 depends on the required load for the crystal where the input capacitance of the IC has to be taken in account.

All circuits use the same receiver amplifier configuration where the biasing of the inverters is realised with the resistors R1, R2 and R3 between the corresponding inputs and outputs. DC decoupling between the amplifiers is made by the capacitors C1, C2 and C3. The capacitors C7 and C8 reduce the bandwidth and noise.

The transmitter power control input TPC is open in these application circuits which means the transmitter control outputs are switched to high power. One can imagine to incorporate a jumper between TPC input and GND. Connecting the TPC input to GND halves the current consumption for the power pulse. This will mainly affect the writing range while the reading range might remain the same.

With additional circuitry the TPC input e.g. can also be used to compensate the field strength drop at low battery voltage of a portable TIRIS reader.

Description of Circuit with Untuned Antenna Circuit

The circuit of Figure 2 uses an antenna coil which is aperiodically coupled to the transmitter and to the receiver. Reference level for the coil is the positive supply voltage VSP. Depending on the needed reading / writing range of the system, the inductance of the antenna can vary in a wide range.

In transmit mode the output TXLO drives the coil directly. The coil current is limited by the resistors R4 and R5.

During receive mode the N-Chn MOSFET of the output TXLO is open and the receive signal induced in the coil is fed via the capacitor C1 to the input A1IN of the amplifier A1. The resistors R4 and R5 reduce a possible resonance between the antenna coil L_Ant and any capacitance of the circuit during transmit and receive phase.

It can be understood that operating range is very limited with such a low power pulse. With an air coil antenna with a diameter of about 3cm, the writing range for a card transponder is about 5 to 15 mm. Small stick transponders must be inside the antenna coil. For such a short reading / writing range it is important, especially for a card transponder application, neither to use a big ferrite antenna for the RF Module nor that the antenna coil forms a resonance circuit. Because of the close coupling, both antenna types will detune the antenna circuit of the transponder so much that operating might fail at this close distance.

Application for such a short reading distance can be areas with a rugged environment where contactless identification is an advantage or even necessary.

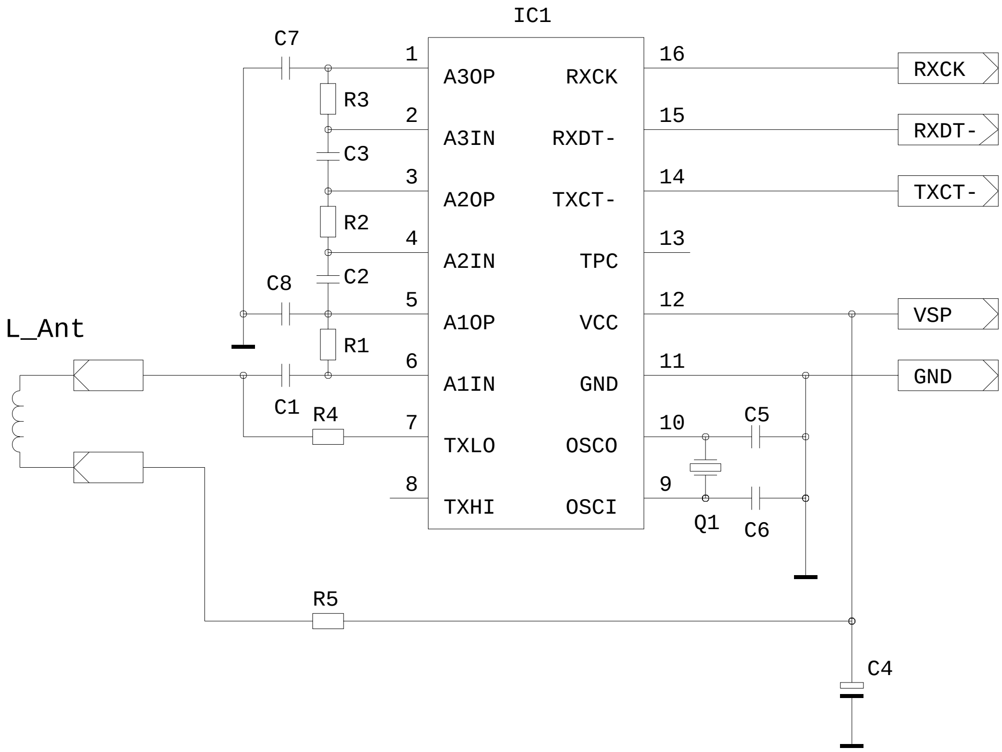

Figure 2: Circuit Diagram for RF Module with Untuned Antenna Circuit

Table 2: Component List for RF Module of Figure 2

Pos.	Ref.	Description	Value
1	C1	Cer. Capacitor	1nF, 50V
2	C2	Cer. Capacitor	1nF, 50V
3	C3	Cer. Capacitor	1nF, 50V
4	C4	Capacitor	4.7µF, 10V
5	C5	Cer. Capacitor	22pF, 50V
6	C6	Cer. Capacitor	22pF, 50V
7	C7	Cer. Capacitor	33pF, 50V
8	C8	Cer. Capacitor	33pF, 50V
9	IC1	TIRIS ASIC	RI45538
10	L_Ant.	Antenna	~500µH
11	Q1	Crystal	17.1776MHz
12	R1	Resistor	1MOhm
13	R2	Resistor	1MOhm
14	R3	Resistor	1MOhm
15	R4	Resistor	470Ohm
16	R5	Resistor	470Ohm

Description of Circuit for an Antenna with Low Q Factor

In the circuit of Figure 3 the antenna coil L_Ant and the capacitor C9 forms a resonant circuit for the transmit frequency of 134.2 kHz. With a Q factor in the range of 5 for the total antenna circuit the tolerance of the antenna coil L_Ant is uncritical if a low tolerance for C9 was chosen.

The push / pull power stage works in series with the antenna circuit and uses complimentary power MOSFETs which are suited to be driven by "logic level". The gates of the MOSFETs are driven by the two complimentary open drain transmitter outputs TXLO and TXHI of the RFM IC RI45538.

In this circuitry both MOSFETs are switched on via the resistor R5 and together with the input capacitance of the MOSFETs it results in a delayed rise of the corresponding gate voltages. Because switching off the MOSFETs is done directly by the outputs of the IC, it is supposed to be faster. This prevents that both transistors T1 and T2 are conductive at the same time which would generate a short circuit current flowing across T1 and T2 and producing current spikes on the VSP line. This is especially important if fast switching MOSFETs with low gate threshold voltage and low R_DSon are used at low temperature.

During receive mode the output TXLO is open and output TXHI (pin 8) is switched to VCC. Therefore the transistor T1 is switched off and transistor T2 switches the capacitor C9 to GND because its gate is on high level via resistor R5. Due to the low Q of the antenna circuit the difference of the insertion loss for the "low bit" frequency at about 134 kHz compared to the loss for the "high bit" frequency at about 122 kHz is low and an extra circuit for 122 kHz is not needed. Although there is the low pass filter R4 / C10 in the receiver path, the total selectivity is low and can be a disadvantage in a noisy environment where an improved filter must be implemented instead of the R4 / C10 combination.

This circuit can be used for application where the Q factor and the inductance of the antenna coil is reduced very much because the antenna coil must be placed close to an iron, steel or similar metal environment.

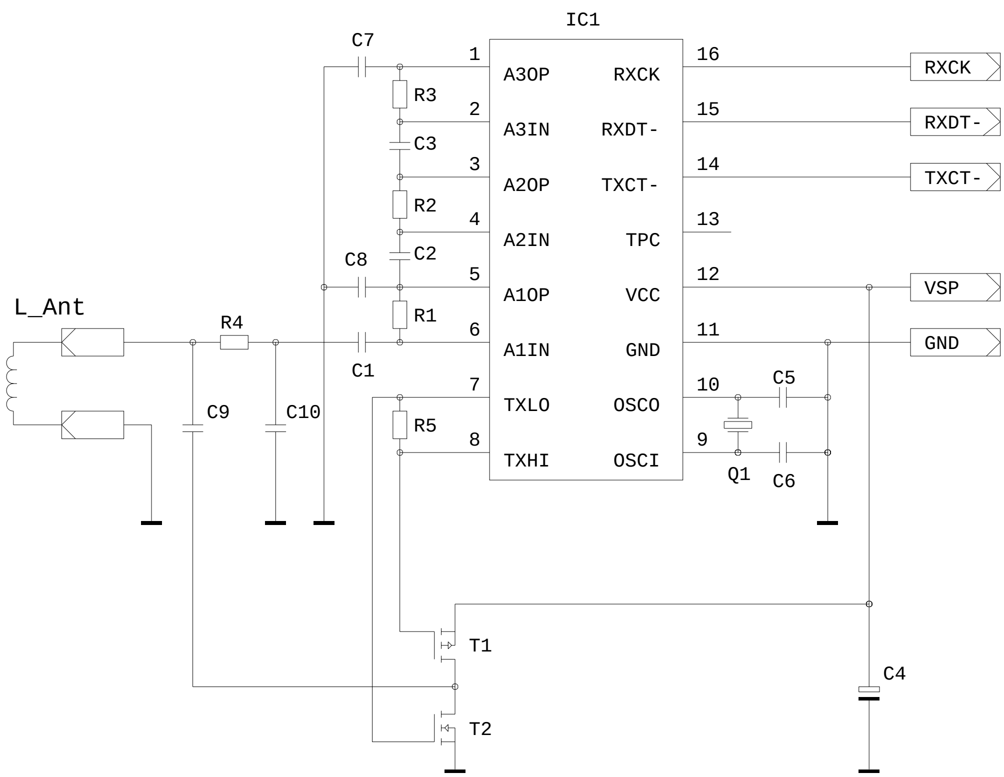

Figure 3: Circuit Diagram of RF Module for Antenna with Low Q Factor

Table 3: Component List for RF Module of Figure 3

Pos.	Ref.	Description	Value
1	C1	Cer. Capacitor	1nF, 50V
2	C2	Cer. Capacitor	1nF, 50V
3	C3	Cer. Capacitor	1nF, 50V
4	C4	Capacitor	4.7µF, 10V
5	C5	Cer. Capacitor	22pF, 50V
6	C6	Cer. Capacitor	22pF, 50V
7	C7	Cer. Capacitor	33pF, 50V
8	C8	Cer. Capacitor	33pF, 50V
9	C9	Film Capacitor	47nF, 2%
10	C10	Cer. Capacitor	1nF, 50V
11	IC1	TIRIS ASIC	RI45538
12	L_Ant.	Antenna	27µH, Q ~ 5
13	Q1	Crystal	17.1776MHz
14	R1	Resistor	1MOhm
15	R2	Resistor	1MOhm
16	R3	Resistor	1MOhm
17	R4	Resistor	8.2kOhm
18	R5	Resistor	220Ohm
19	T1	P-Chn MOSFET	2SJ182
20	T2	N-Chn MOSFET	2SK974

Description of Circuit for Antenna with Medium Q Factor

The circuit of Figure 4 uses an antenna coil with the Q factor of about 20. Compared with the circuit of Figure 3 much higher resonance current flows through the coil. This also means that for same reading distance and supply voltage the inductance can be higher and the corresponding capacitor can be smaller.

The transmitter power stage works similar to the circuit of Figure 3. The antenna circuit consist of the antenna coil L_Ant, the main resonance capacitor C9 which is connected to the circuit via the power stage. Additionally the capacitor C10 which is grounded during transmit phase via the twin diode D1 belongs to the antenna circuit. Because of the higher Q factor of the antenna circuit the tolerance for L_Ant, C9 and C10 must be very low or alignment components must be added for exact tuning.

In receive mode the capacitor C10 couples the receive voltage of the antenna circuit to the receiver input filter consisting of the inductance L1 and the two capacitors C11 and C12. The antenna and the receiver input circuits forms an bandpass filter with the passband characteristic shown in Figure 5a. The shown bandwidth is suggested for applications where the standard transponders are applied over the temperature range of -40 to +85 °C. To keep the shown bandwidth within the 6 dB range the component for the receiver input circuit must also have low tolerance or the circuit must be aligned. Figure 5a shows the filter curve over a range of 50 kHz to 500 kHz.

The resistors R4, R5 and R6 protect the IC RI45538 against transients when long cables are connected to these input and outputs.

This circuit is suited for applications where wide band noise exists.

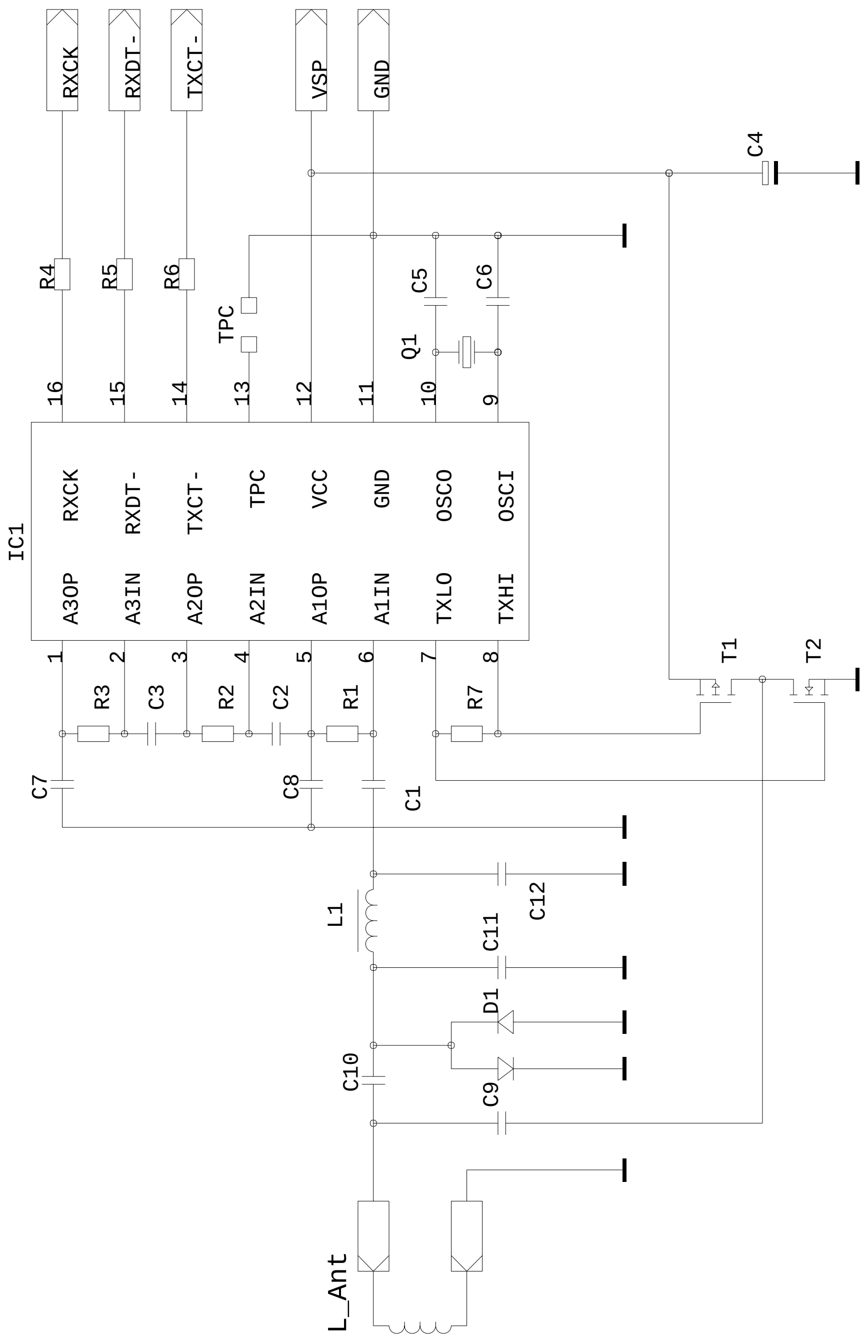

Figure 4: Circuit Diagram of RFM for Antenna with Medium Q Factor

Table 4: Component List for RF Module of Figure 4

Pos.	Ref.	Description	Value
1	C1	Cer. Capacitor	1nF, 50V
2	C2	Cer. Capacitor	1nF, 50V
3	C3	Cer. Capacitor	1nF, 50V
4	C4	Capacitor	4.7µF, 10V
5	C5	Cer. Capacitor	22pF, 50V
6	C6	Cer. Capacitor	22pF, 50V
7	C7	Cer. Capacitor	33pF, 50V
8	C8	Cer. Capacitor	33pF, 50V
9	C9	Cer. Capacitor	15nF,. 50V, 2% (1%)
10	C10	Cer. Capacitor	1.8nF, 50V, 2%
11	C11	Cer. Capacitor	4.7nF, 50V, 2%
12	C12	Cer. Capacitor	3.9nF, 50V, 2%
13	D1	Twin Diode	BAV99
14	IC1	TIRIS ASIC	RI45538
15	L_Ant.	Antenna	85µH, 2%, Q ~ 19 @ 134kHz
16	L1	Coil	680µH, 2% Q ~ 28 @ 134KHz
17	Q1	Crystal	17.1776MHz
18	R1	Resistor	1MOhm
19	R2	Resistor	1MOhm
20	R3	Resistor	1MOhm
21	R4	Resistor	330Ohm
22	R5	Resistor	330Ohm
23	R6	Resistor	1kOhm
24	R7	Resistor	220Ohm
25	T1 / T2	P-Chn/N-Chn MOSFET	MMDF2C05E

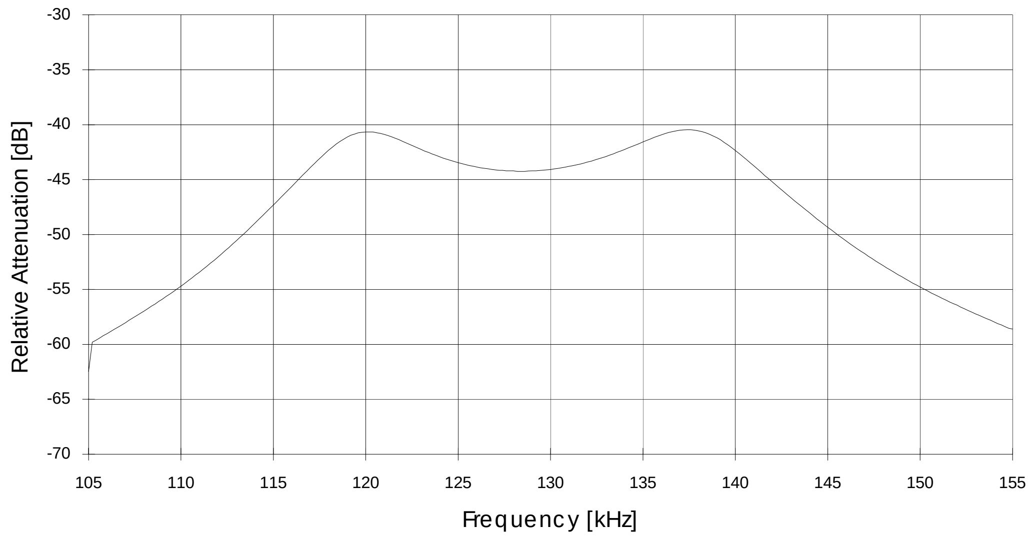

Figure 5a: Frequency Response of the Input Circuit
Scan Width = 50kHz

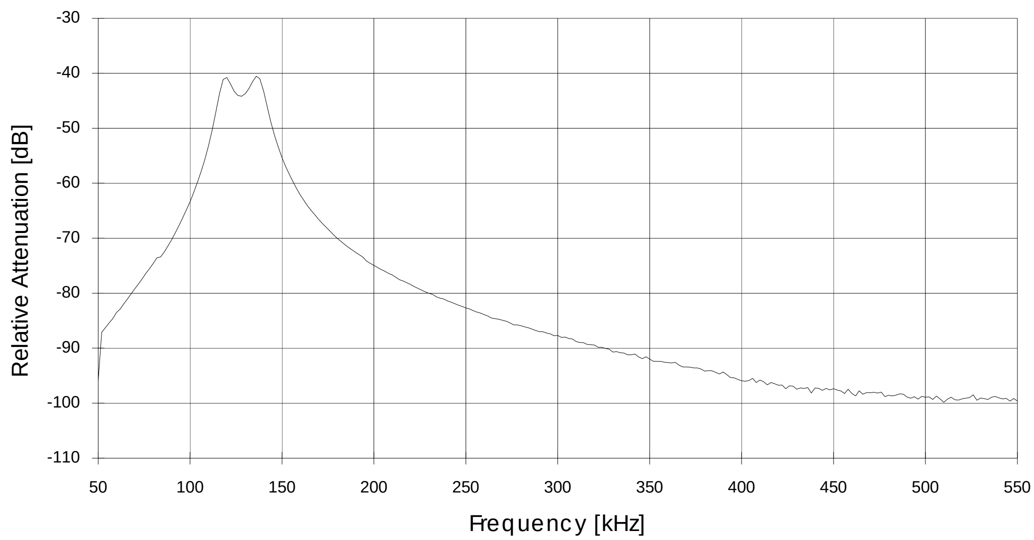

Figure 5b: Frequency Response of the Input Circuit
Scan Width = 500kHz

Description of Circuit with Tapped Antenna Coil

The main differences of the circuit in Figure 6 to the previous circuits are the tapped antenna coil and the bipolar PNP transistor used in the power stage. Although a tapped coil and the third wire may seem to be more complicated, this circuit has some advantages on the transmitter and on the receiving side.

The antenna circuit consists of the antenna coil L_Ant, the resonance capacitor C1 and the resistor R1. The coil has a relatively high inductance. To keep the Q of the antenna circuit low and to avoid the use of a very thin wire for the coil the resistor R1 adjusts the Q of the antenna circuit to the desired low value.

The most advantage using a coil with a high number of turns is the high signal voltage for the receiver. This results in a better matching to the relative high input impedance of the inverter amplifier of the ASIC. It also improves the signal to noise ratio and leads finally to a longer receiving range without an extra receiver amplifier.

Because of the high inductance of the antenna coil, a push/pull stage in series with the resonance circuit cannot bring enough energy into the circuit with a low supply voltage. Therefore a single ended bipolar transistor stage and a tap to the antenna coil were chosen to drive the antenna circuit. With varying the tap one can adapt the desired energy (charging range) to a given supply voltage. Because in this application the resonance current of the antenna circuit does not flow via the transistor T1, a bipolar transistor can be used. To keep its power dissipation low, it is used as a switch with a short duty cycle. Therefore the input TPC is set to "low".

The IC2 is a single MOS gate which inverts the data output RXDT- to work with standard TIRIS control modules. The gate of course is not needed if a dedicated control circuit is used. Table 5 lists the used components for the circuit of Figure 6. As an example for the simplicity of this circuit the Figure 7 shows a single side assembled PCB and Figure 8 its dimension.

Together with the air coil antenna shown in Figure 8 and a 32 mm transponder, the module reaches a read range of about 10 cm. Data for the antenna coil are as follow:

N1 = 117 turns varnish coated copper wire with 0.1mm diameter
N2 = 4 turns varnish coated copper wire with 0.1mm diameter
L1 = about 1.58 mH; Q about 28
L2 = about 3.7 uH, Q about 1.5

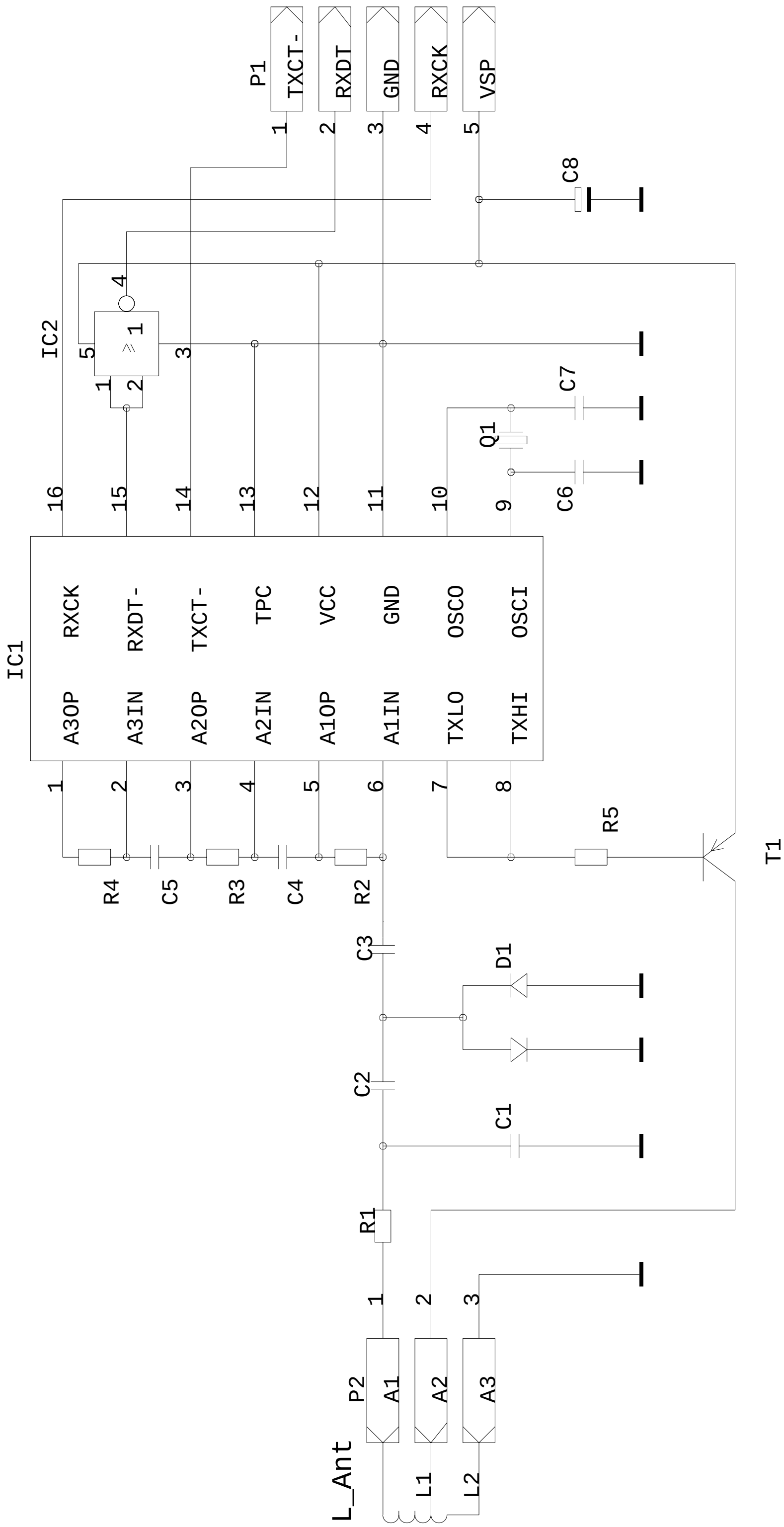

Figure 6: Circuit Diagram of RF Module with Tapped Antenna Coil

Table 5: Component List for RF Module of Figure 6

Pos.	Ref.	Description	Value
1	C1	Cer. Capacitor	820pF, 200V, 2%, 1206
2	C2	Cer. Capacitor	100pF, 200V, 5%, 1206
3	C3	Cer. Capacitor	470pF, 50V, 10%, 0805
4	C4	Cer. Capacitor	470pF, 50V, 10%, 0805
5	C5	Cer. Capacitor	470pF, 50V, 10%, 0805
6	C6	Cer. Capacitor	22pF, 50V, 10%, 0805
7	C7	Cer. Capacitor	22pF, 50V, 10%, 0805
8	C8	Capacitor	4.7µF, 10V, 10%, 0805
9	D1	Double Diode	BAV99, SOT23
10	Q1	Crystal	17.1776MHz
11	R1	Resistor	68Ohm, 10%, 1206
12	R2	Resistor	1MOhm, 10%, 0805
13	R3	Resistor	1MOhm, 10%, 0805
14	R4	Resistor	1MOhm, 10%, 0805
15	R5	Resistor	330Ohm, 10%, 0805
16	IC1	TIRIS ASIC	RI45538
17	IC2	Single Gate	TC4S01F
18	T1	PNP-Transistor	BSP33

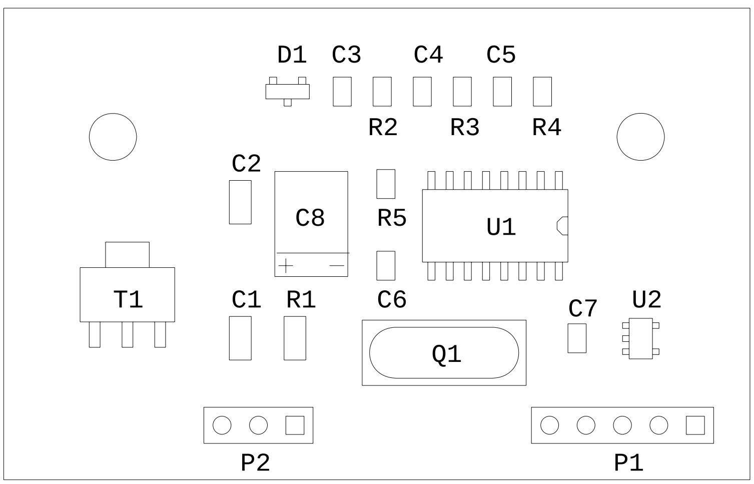

Figure 7: Component Placement

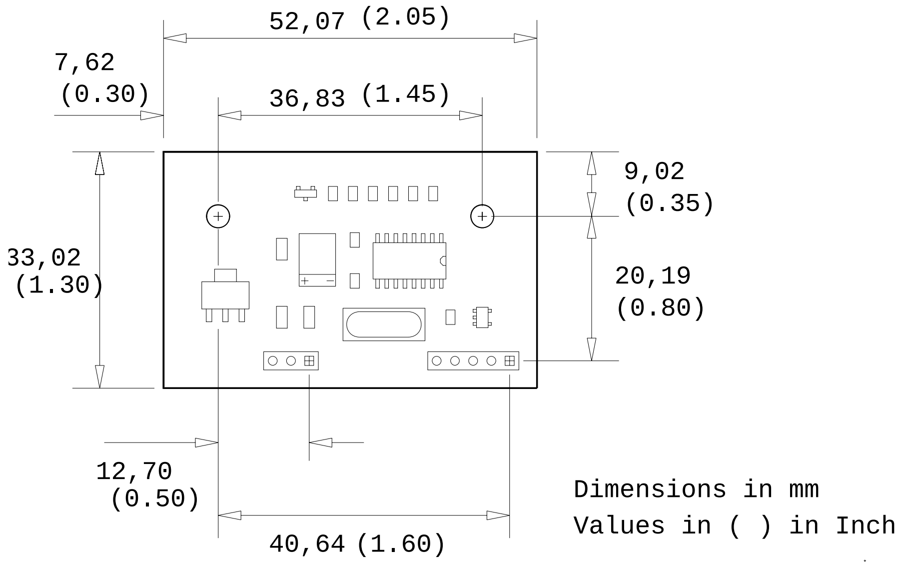

Figure 8: Dimension of the Sample Board

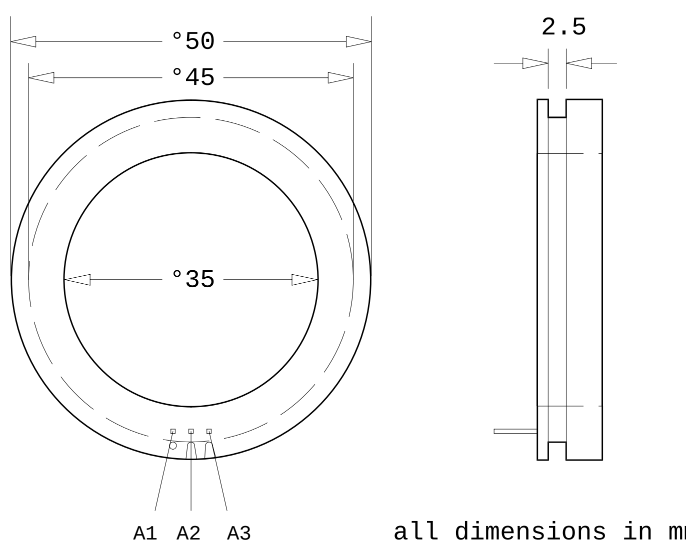

Figure 9: Antenna Coil Former Used for the Circuit of Figure 6