

TIRIS RF-Module IC for Automotive
RI-RFM-006A

Reference Guide

December 1996

TIRIS Technology by
Texas Instruments™

SCBU036

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Contents

1	Overview	4
2	Features	4
3	TIRIS™ System Configuration (Schematic Diagram)	4
4	Internal Block Diagram and Pin Assignment	5
5	Description of Pins	6
6	Function and Operation	6
	6.1 General	6
	6.2 Sending Mode	7
	6.3 Receiving Mode	7
7	Electrical Specifications	9
	7.1 Absolute Maximum Rating	9
	7.2 Recommended Operating Conditions.....	10
8	Input-Output Specifications	10
	8.1 Transmitter Signal I/O Timing.....	10
	8.2 Receiver Signal I/O Timing.....	11
9	Dimensional Outline Drawing – 16-pin SOP	12
10	Applied Circuit Configuration – Example	12
11	Typical Transmitter Circuit Configuration	13
12	Typical Receiver Circuit Configuration	14
13	Typical Antenna Circuit Configuration	15
14	Precautions for Mounting and Actual Use	16
	14.1 Power Supply Line	16
	14.2 Wiring for Antenna Circuit	17
15	Package	18

TIRIS RF-Module IC for Automotive

1 Overview

RI-RFM-006A is a CMOS-technology based RF-module IC which integrates all transmitter-receiver functions required for constructing a **TIRIS** Read-Write System into one single chip.

RI-RFM-006A consists of a transmitter signal control logic which generates signals for transmission and for sending the data you wrote to a remote **TIRIS** transponder, and a receiver amplifies and demodulates frequency shift keyed (FSK) signals received from this transponder.

Therefore, RI-RFM-006A is beneficially usable for constructing, in particular, a compact **TIRIS** Read-Write System at a reduced cost. Furthermore, demodulation of the FSK signals received in its receiver from a remote transponder is entirely digitized; this completely eliminates the need of regulations and lessens the number of required external parts, thus enhancing the operational reliability of the system.

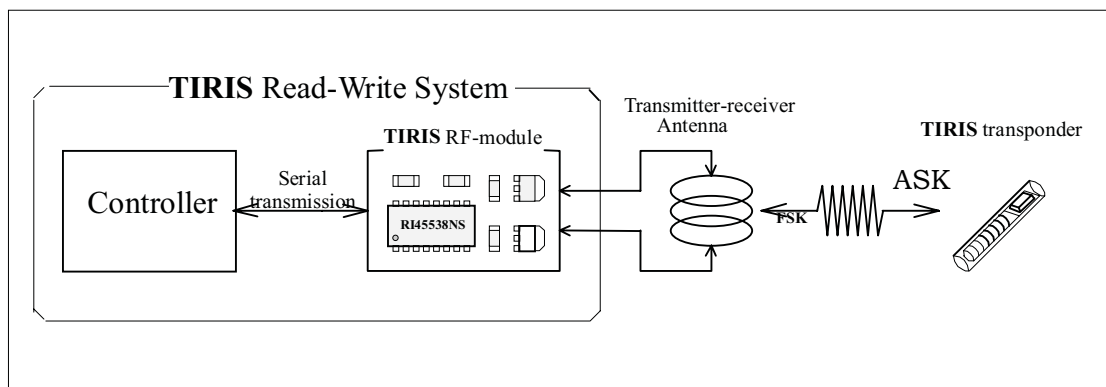
2 Features

The **TIRIS** RF-Module IC for Automotive Application, RI-RFM-006A, provides the following features amongst others:

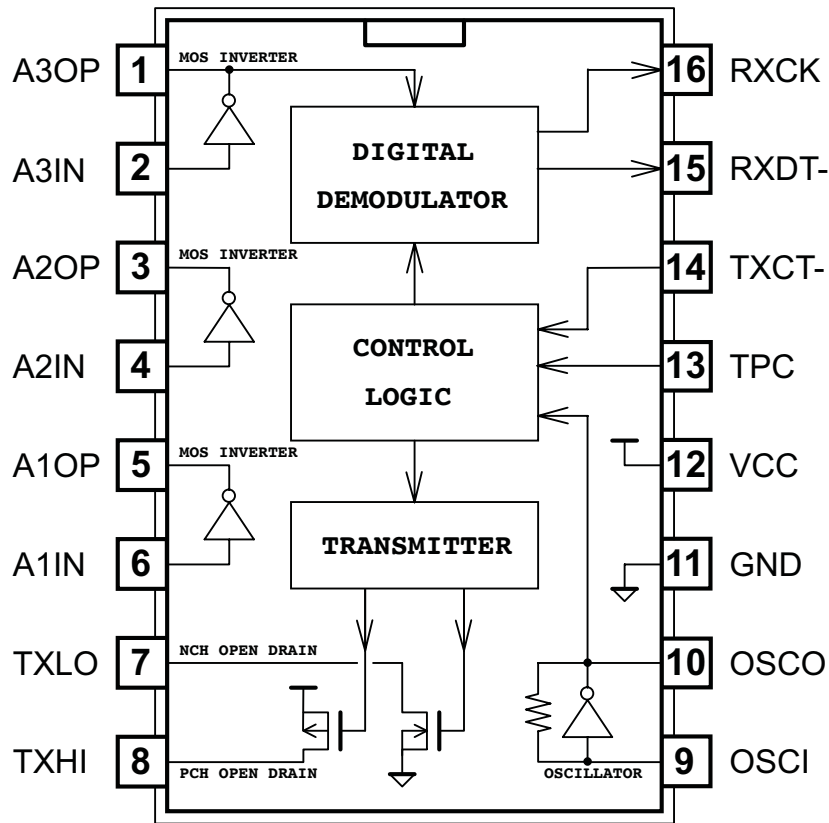
- It incorporates a transmitter circuit with power selector and an open drain transmission power predriver.
- Also incorporated are a receiver signal amplifier and a digitized FSK signal demodulator.
- I/O specifications: Conform to **TIRIS** standard RF-module specifications, with available signals of TXCT–, RXDT–⁽¹⁾ and RXCK only.
- Operating supply voltage: 4.5 V to 5.5 V
- Operating temperature range: –40°C to 85°C
- Package: 16-pin SO package
- Structure: CMOS process

⁽¹⁾ For RXDT– signals, this RF-module has a reverse polarity in relation to **TIRIS** standard RF-modules. See the section “Description of Pins” for more information.

3 TIRIS™ System Configuration (Schematic Diagram)



4 Internal Block Diagram and Pin Assignment



Name	I/O Function	Name	I/O Function
A3OP	CMOS INVERTER-3/FSK SIGNAL OUTPUT	OSCI	OSCILLATOR INPUT(17.1776MHz typ.)
A3IN	CMOS INVERTER-3/FSK SIGNAL INPUT	OSCO	OSCILLATOR OUTPUT
A2OP	CMOS INVERTER-2 OUTPUT	GND	GND(POWER SUPPLY)
A2IN	CMOS INVERTER-2 INPUT	VCC	VCC(POWER SUPPLY)
A1OP	CMOS INVERTER-1 OUTPUT	TPC	TX-POWER Hi/Lo SELECT SIG. INPUT
A1IN	CMOS INVERTER-1 INPUT	TXCT-	TX-OUTPUT CONTROL SIGNAL INPUT
TXLO	TX-OUTPUT(NCH OPEN DRAIN OUTPUT)	RXDT-	RX-DATA("L"="1", "H"="0") OUTPUT
TXHI	TX-OUTPUT(PCH OPEN DRAIN OUTPUT)	RXCK	RX-DATA CLOCK OUTPUT

5 Description of Pins

Pin #	Signal	I/O	Description
1	A3OP	O	Signal output from CMOS inverter-3 amplifier; this pin is connected to the internal FSK signal digital demodulator.
2	A3IN	I	Signal input to CMOS inverter-3 amplifier; if an external circuit is used to amplify FSK signals, the amplified signals are input through this pin.
3	A2OP	O	Signal output from CMOS inverter-2 amplifier.
4	A2IN	I	Signal input to CMOS inverter-2 amplifier.
5	A1OP	O	Signal output from CMOS inverter-1 amplifier.
6	A1IN	I	I 16. Signal input to CMOS inverter-1 amplifier.
7	TXLO	Negative open drain output	Negative level output of transmission signals; this output drives the n-channel MOSFET used as antenna driver.
8	TXHI	Positive open drain output	Positive level output of transmission signals; this output drives the p-channel MOSFET used as antenna driver.
9	OSCI	I	Signal input to 17.1776 MHz master clock oscillator.
10	OSCO	O	Signal output from 17.1776 MHz master clock oscillator.
11	GND	–	Negative power supply.
12	VCC	–	Positive power supply.
13	TPC	I, w/pull-up resistor	Input of transmission power selection signals (High-Low). A Low level signal input through this pin substantially lowers the power during transmission
14	TXCT–	I, w/pull-up resistor	Input of transmission output control signals (Transmit-Receive Mode Selector). A Low level signal input through this pin outputs a transmission signal to either “TXLO/TXHI” pin while a High level signal input turns the mode to Receive and activates the internal FSK signal digital demodulator.
15	RXDT–	O	Serial output of demodulated FSK signal bit data. Negative level output when the bit data received from the remote transponder is “1”, and positive level output when it is “0”. Note: The RI-RFM-006A has a reverse polarity in relation to TIRIS standard RF-modules.
16	RXCK	O	Synchronous clock output of demodulated FSK signal data; a clock signal synchronized with the “RXDT–” signal is output.

6 Function and Operation

6.1 General

This RF-module IC counts on two operating modes:

Sending Mode – This mode is active when the “TXCT–” pin is set to L-level. A remote **TIRIS** transponder can be charged up and ID code can be sent to that transponder in this mode.

Receiving Mode – This mode is active when the “TXCT–” pin is set to H-level. FSK signals sent from a remote **TIRIS** transponder are received and demodulated in this mode.

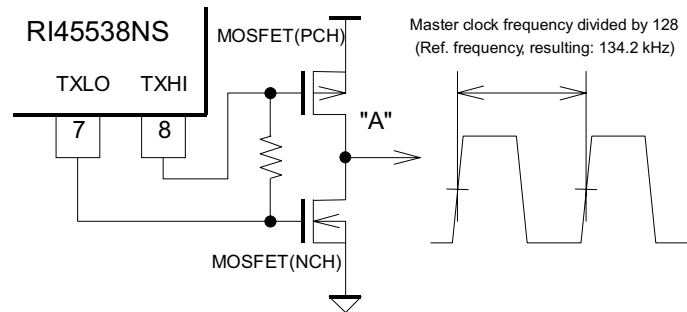
Therefore, by switching over these modes using an external controller, data communications with a **TIRIS** transponder can be made.

Note that this RF-module IC is exclusively designed to provide the user with a simple signal modulator-demodulator (modem) function for data communications with a remote **TIRIS** transponder, based on the appropriate data modulation-demodulation specifications. And therefore, it does not incorporate error detection, data allotment nor other similar data processing functions in terms of protocol and data formats.

(*) In both transmit and receive modes, this RF-module IC modulates and demodulates signals by logical operation based on the incorporated master clock. This means that the modulating-demodulating performance characteristics of this IC are directly affected by the frequency accuracy and variation of its master clock (normal frequency is 17.1776 MHz). Therefore, the user is requested to select an oscillating element or an external clock which is compatible with the remote **TIRIS** transponder to be used (see the section describing the specifications “fexc”, “fL” and “fH”).

6.2 Sending Mode

In the Sending Mode, the frequency of the IC master clock (normal value: 17.1776 MHz) is divided by 128. The resulting clock signal then has a frequency of 134.2 kHz (normal value). This resulting signal is output as a composite signal for “TXHI” and “TXLO” terminals (pins) to drive the MOSFET which is incorporated as an antenna resonance circuit driver, as illustrated below.



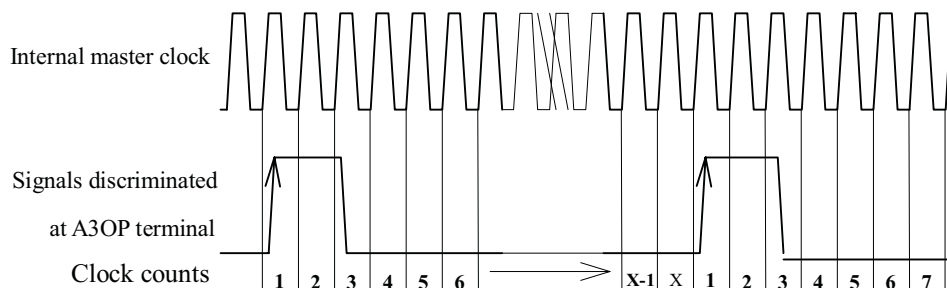
When the IC is in the Receiving Mode, its “TXHI” terminal is fixed at positive level and the “TXLO” at high impedance. As a result, the output terminal “A” of the MOSFET used as an antenna resonance circuit driver is fixed at negative level.

Note that when the IC is in the Sending Mode, its “RXDT–” terminal is always fixed at positive level and as a consequence, the IC’s FSK signal demodulator remains deactivated although data clock signals, which are transmitted at a frequency resulting from division of the “A3IN” terminal signal frequency by 16, are output to the “RXCK”.

6.3 Receiving Mode

In the Receiving Mode, the frequency-shift-keyed data signals are sequentially digitized to discriminate their frequencies by binary notation (high-low) and demodulate them into bit strings consisting of bit data “1” and “0”.

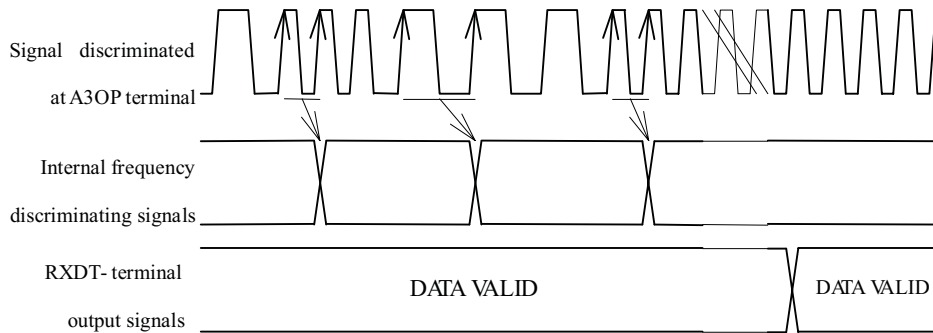
For binary discrimination of signal frequencies between high and low, the frequency level of each FS-keyed signal is measured from its leading edge at the “A3OP” terminal through to the next leading edge by count of the internal master clock, as shown below. The threshold for this counted value (x in the diagram below) is fixed at 132; when the clock count is over 132, it results in a negative level output at the “RXDT–” terminal (bit data “1”), and when the clock count does not reach 132, a positive level output at the same terminal (bit data “0”), respectively.



Function and Operation

As the normal frequency of the internal master clock is 17.1776 MHz, one clock count is equivalent to 130.133... kHz (17.1776 MHz divided by 132 = 130.133... kHz). Accordingly, a signal is identified as bit data "1" with the resulting negative level output at the "RXDT-" terminal when the signal frequency at the "A3OP" terminal is 130.133... kHz or less, and it is identified as bit data "0" with the resulting positive level output at the "RXDT-" terminal when the signal frequency at the "A3OP" terminal is over 130.133... kHz.

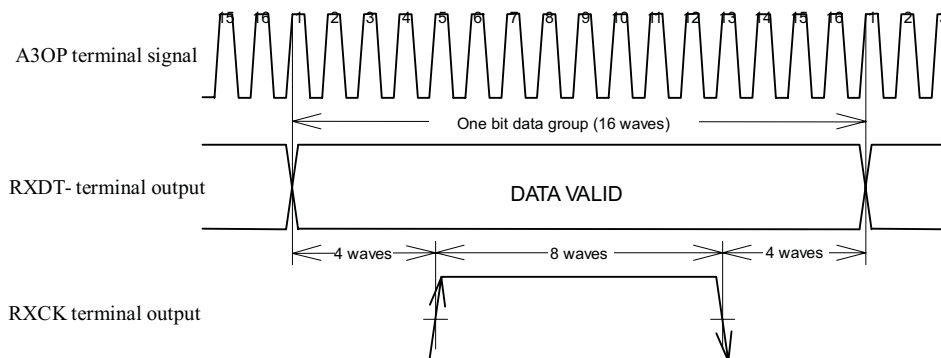
An additional feature is included to maximize the stability of the above-mentioned FSK signal demodulating system based on binary notation: the system incorporates a circuit which disables definition of an "RXDT-" signal unless more than four consecutive FS-keyed signal waves are identified within the same frequency band during binary discrimination. This protects the once defined "RXDT-" signal in the bit data form from being affected by sporadic events. For instance, even when its discrimination result is sporadically inverted due to some noise effects, it is not affected if only three or less consecutive FS-keyed signal waves are identified at the "A3OP" terminal. (See the diagram below.)



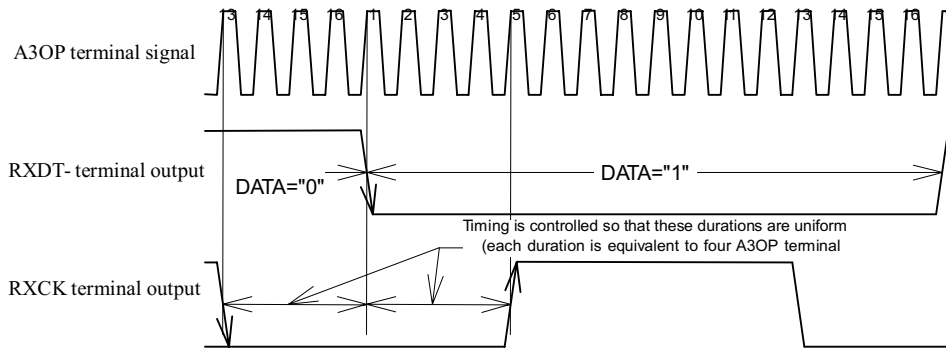
Note: For the timing between "A3OP" and "RXDT-" signals, refer to the section describing "Input-Output Specifications".

The signals demodulated through the above-mentioned process are sequentially output from the "RXDT-" terminal in bit strings ("1" or "0"). To delimit these continuous bit strings, clock signals are output from the "RXCK" terminal in synchronization with each bit data.

In normal operating conditions (when data communication can be properly performed between the RI-RFM-006A and a TIRIS transponder), each bit data group sent from the remote transponder is composed of sixteen consecutive signal waves belonging to the same frequency band (consisting of two wave groups, 134.2-kHz high and 123.2-kHz low in terms of normal values). Therefore, clock signals at a frequency resulting from a simple division of the "A3OP" terminal signal frequency by 16, are output from the "RXCK" terminal. Then, each "RXCK" clock signal is controlled for output so that its first transition falls after four consecutive "A3OP" signal waves from the "RXDT-" signal change point. This enables an external controller to obtain the relevant bit data without fail provided that each "RXDT-" signal is fetched well timed with the first transition of each "RXCK" signal. (See the diagram below.)



Sometimes at starting or during data receiving, some bit data group (composed of sixteen consecutive signal waves belonging to the same frequency band) may be affected by interference noise, this causing the number of its waves to vary and the consequent synchronous discrepancy between “RXDT-“ and “RXCK” signals. To correct this discrepancy, the sixteenth dividing counter of frequency incorporated in this RF-module IC for “RXCK” clock signal generation are always reset at the moment at which any internal demodulated bit data changes from “0” to “1” so that “RXCK” terminal signals are forcibly output at L-level with the timing shown below. This correction is made automatically regardless of whether or not receiving signals are properly input. (The frequency dividing counter is not reset at bit data change from “1” to “0”.)



Note: For details about timing among these signals, refer to the section describing “Input- Output Specifications”.

7 Electrical Specifications

7.1 Absolute Maximum Rating

Supply voltage	(V_{CC})	-0.5 to 7.0V
Input voltage range	(V_i)	-0.5 to 7.0V
Output voltage range	(V_o)	-0.5 to 7.0V
Input clamping current	(I_{ik})	±20 mA
Output clamping current	(V_{ok})	±20 mA
Output current	($I_{out}(V_{out}=0 \text{ to } V_{CC})$)	±25 mA
Operating temperature	(T_A)	-40 to +85°C
Storage temperature	(T_{stg})	-65 to +150°C

7.2 Recommended Operating Conditions

7.2.1 Recommended Operating Conditions

	MIN	MAX	UNIT
Supply voltage, V_{CC}	3.5	5.5	V
High-level input voltage, V_{IH}	$0.7 V_{CC}$		V
Low-level input voltage, V_{IL}		$0.2 V_{CC}$	V
Operating free-air temperature, T_A	-40	85	°C

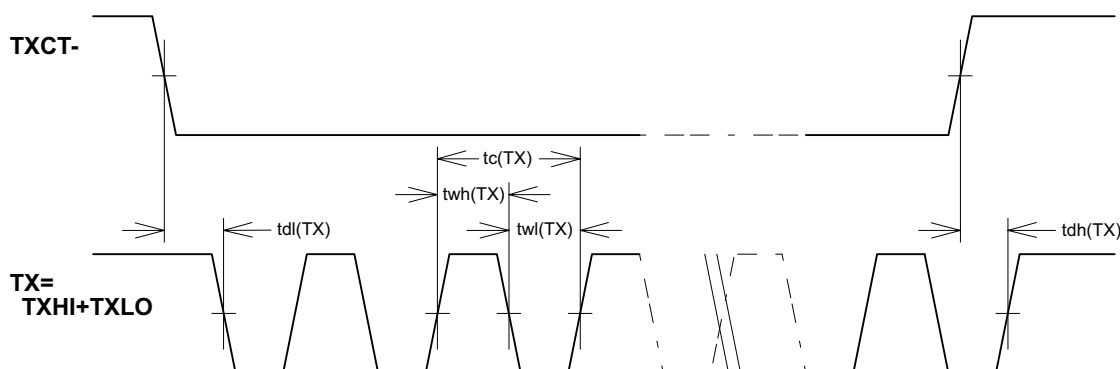
7.2.2 Electrical Characteristics ($V_{CC}=5.0V$, $T_A=25^\circ C$)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
V_{th}	Hysteresis voltage			1.7		V
I_{OH}	High-level output current	$V_{OH}=3.7V$	6.8			mA
	(TXHI)		20			mA
	(A2OP,A3OP)		73			μA
	(A1OP)		144			μA
I_{OL}	Low-level output current	$V_{OH}=0.5V$	-6.8			mA
	(TXLO)		-20			mA
	(A2OP,A3OP)		-72			μA
	(A1OP)		-144			μA
C_i	Input capacitance			7.4		pF
I_{CC}	Supply current			35		mA

Note: Unless otherwise specified, all the voltage values indicated above are those measured versus the "GND" pin of this RF-module IC.

8 Input-Output Specifications

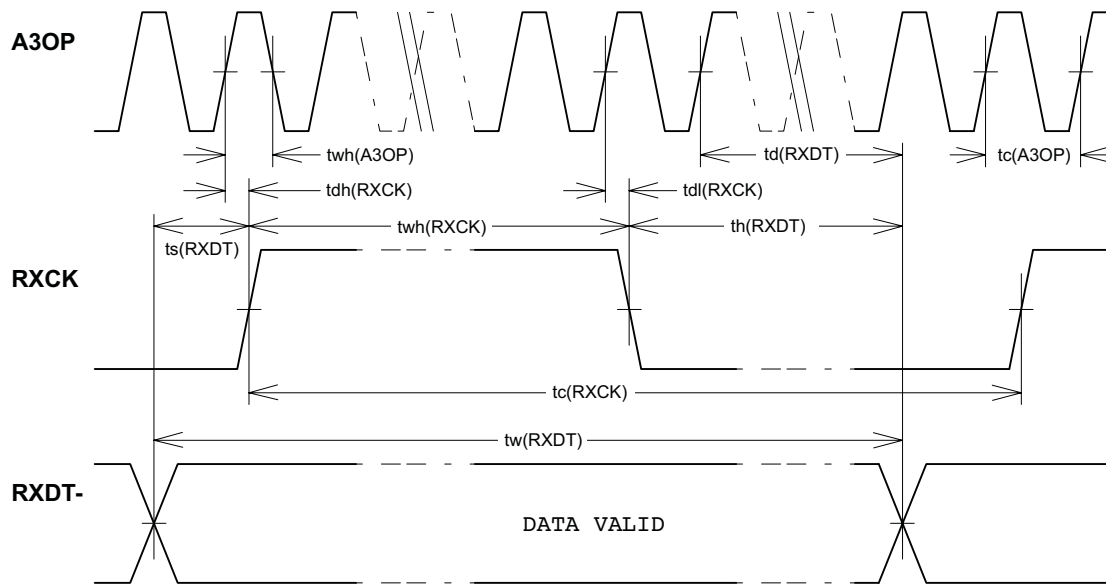
8.1 Transmitter Signal I/O Timing



ITEM	SIGNAL	MIN	TYP	MAX	UNIT
Delay time between TXCT- and TX trailing edges	$t_{dl(TX)}$			$64T_{c(OSC)}$	nS
Delay time between TXCT- and TX leading edges	$t_{dh(TX)}$			$1T_{c(OSC)}$	nS
TX cycle time	$t_{c(TX)}$		$128T_{c(OSC)}$		nS
TX low level pulse duration	$t_{wl(TX)}$		$64T_{c(OSC)}$		nS
TX high level pulse duration	$t_{wh(TX)}$		$64T_{c(OSC)}$		nS

Note: " $T_{c(OSC)}$ " denotes the master clock cycle of this RF-module IC and its normal value is specified at 56.3 ns (1/0.0171776). The same applies hereinafter. "TX" is defined as a composite signal of "TXLO" and "TXHI" signals.

8.2 Receiver Signal I/O Timing



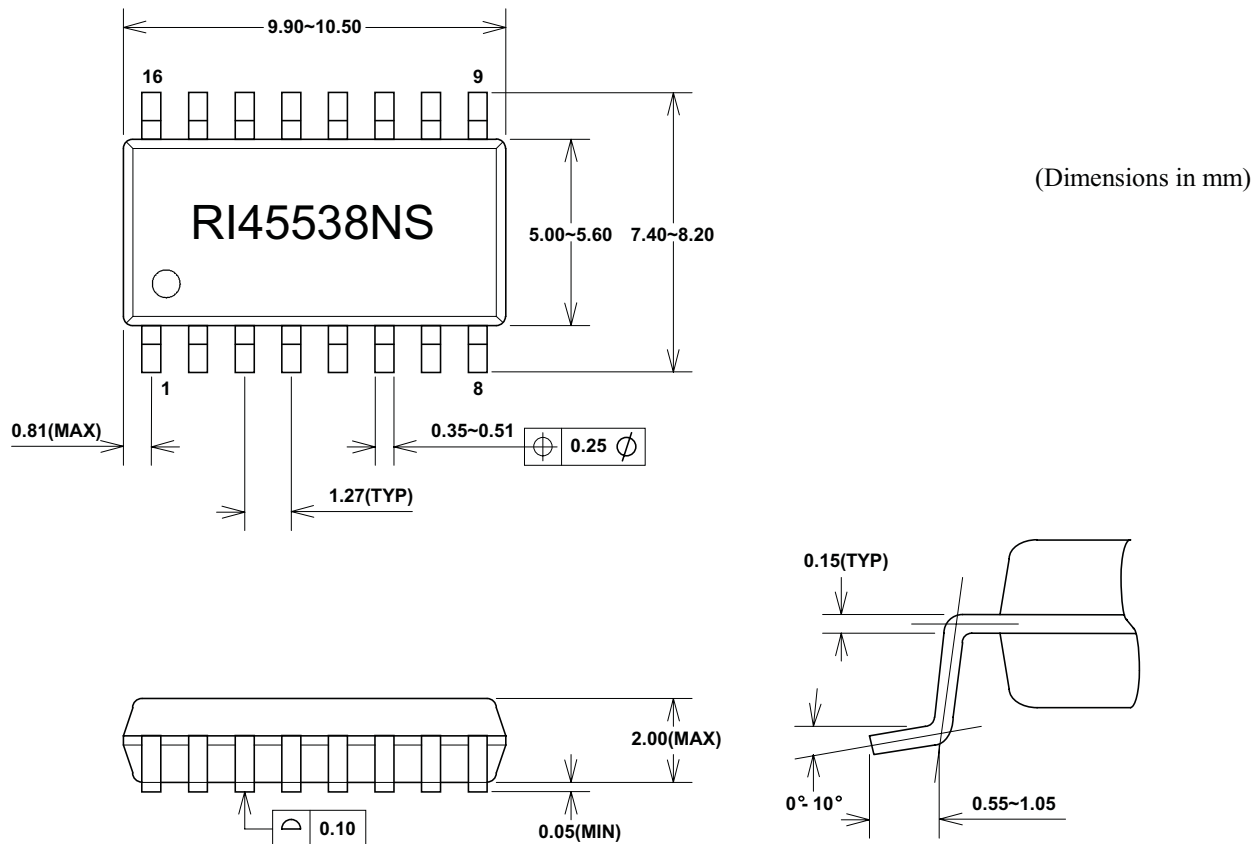
ITEM	SIGNAL	MIN	TYP	MAX	UNIT
A3OP cycle time for normal FSK signal demodulation	$t_{c(A3OP)}$	$2T_{c(OSC)}$			nS
A3OP positive level pulse duration for normal FSK signal demodulation	$t_{wh(A3OP)}$	$1T_{c(OSC)}$			nS
A3OP cycle time for negative level output of RXDT- signal (bit data "1")	$t_{c(A3OP)}$	$132T_{c(OSC)}$			nS
Delay time between A3OP and RXCK leading edges	$t_{dh(RXCK)}$			$1T_{c(OSC)}$	nS
Delay time between A3OP leading edge and RXCK trailing edge	$t_{dl(RXCK)}$			$1T_{c(OSC)}$	nS
RXCK cycle time	$t_{c(RXCK)}$		$16T_{c(A3)}$		nS
RXCK positive level pulse duration	$t_{wh(RXCK)}$		$8T_{c(A3)}$		nS
Delay time from consecutive A3OP identical signal waves to definition of an RXDT- signal	$t_{d(RXDT)}$			$16T_{c(A3)} + 1T_{c(OSC)}$	nS
RXDT- positive/negative level duration, definite	$t_{w(RXDT)}$		$16T_{c(A3)}$		nS
RXDT- signal setup time in relation to RXCK signal	$t_{s(RXDT)}$	$4T_{c(A3)} - 1T_{c(OSC)}$			nS
RXDT- signal hold time in relation to RXCK signal	$t_{h(RXDT)}$	$4T_{c(A3)} - 1T_{c(OSC)}$			nS

Dimensional Outline Drawing – 16-pin SOP

Note: “ $T_{c(A3)}$ ” denotes the signal cycle at the “A3OP” terminal and the above values are based on the condition that a bit data group composed of sixteen consecutive signal waves belonging to the same frequency band (sent from a remote **TIRIS** transponder in normal operating conditions) has been previously input; otherwise, the values shown in the table below shall apply.

ITEM	SIGNAL	MIN	TYP	MAX	UNIT
RXCK cycle time (except for normal signal receiving)	$t_{c(RXCK)}$	$9T_{c(A3)}$			nS
RXCK positive level pulse duration (except for normal signal receiving)	$t_{wh(RXCK)}$	$1T_{c(A3)}$			nS
RXDT– positive/negative level duration, definite (except for normal signal receiving)	$t_{w(RXDT)}$	$9T_{c(A3)}$			nS

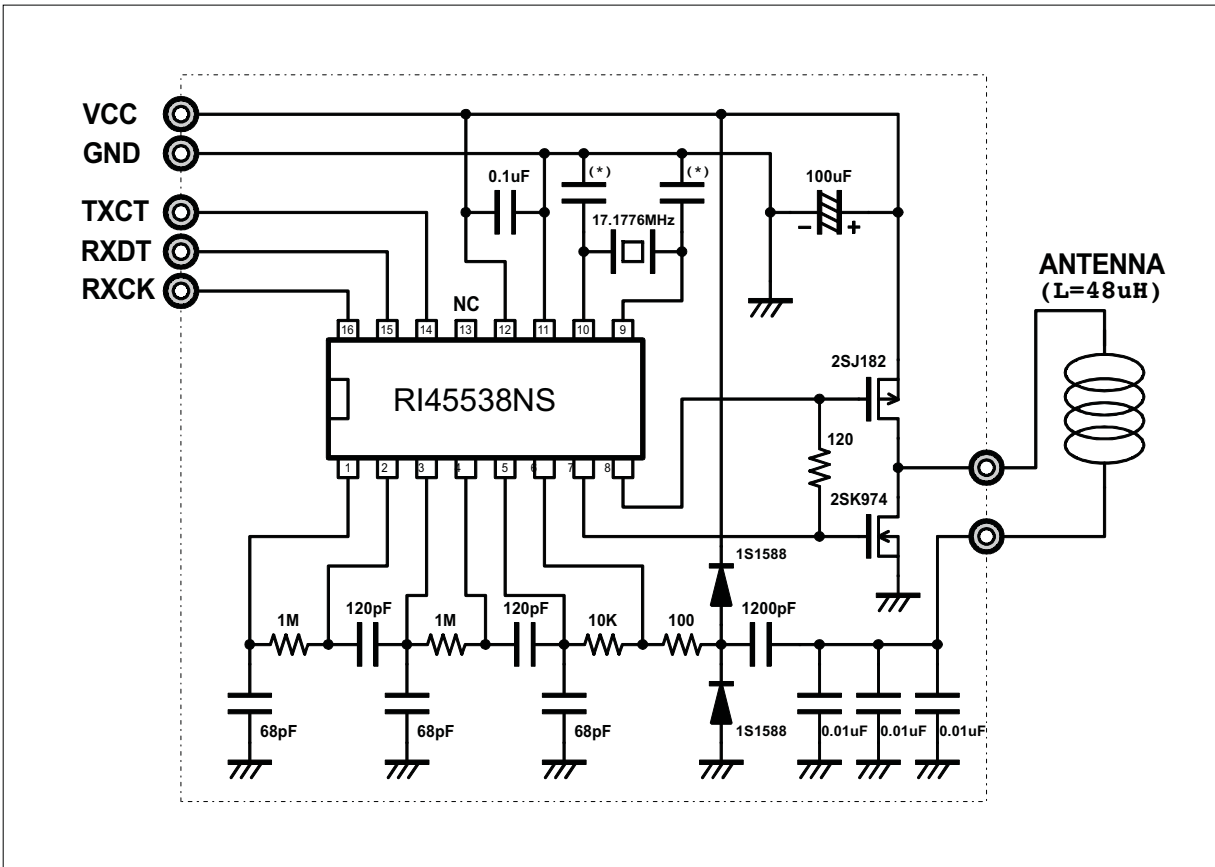
9 Dimensional Outline Drawing – 16-pin SOP



10 Applied Circuit Configuration – Example

Shown below is an example of applied circuit configuration for constructing a **TIRIS** Transmit-Receive RF-module using the RI-RFM-006A. This example illustrates a simplified amplifier circuit for received signals by eliminating a frequency band rejection filter which effectively eliminates external noises and signals out of the frequency band of the response signals from the remote **TIRIS** transponder. In this configuration, therefore, it is assumed that the available data communication distance of the system could be easily affected by environmental conditions.

Note that this is only one of various possible applications. For more information of applied circuit configurations, refer to the Application Handbook issued by our **TIRIS** Operation Dept.

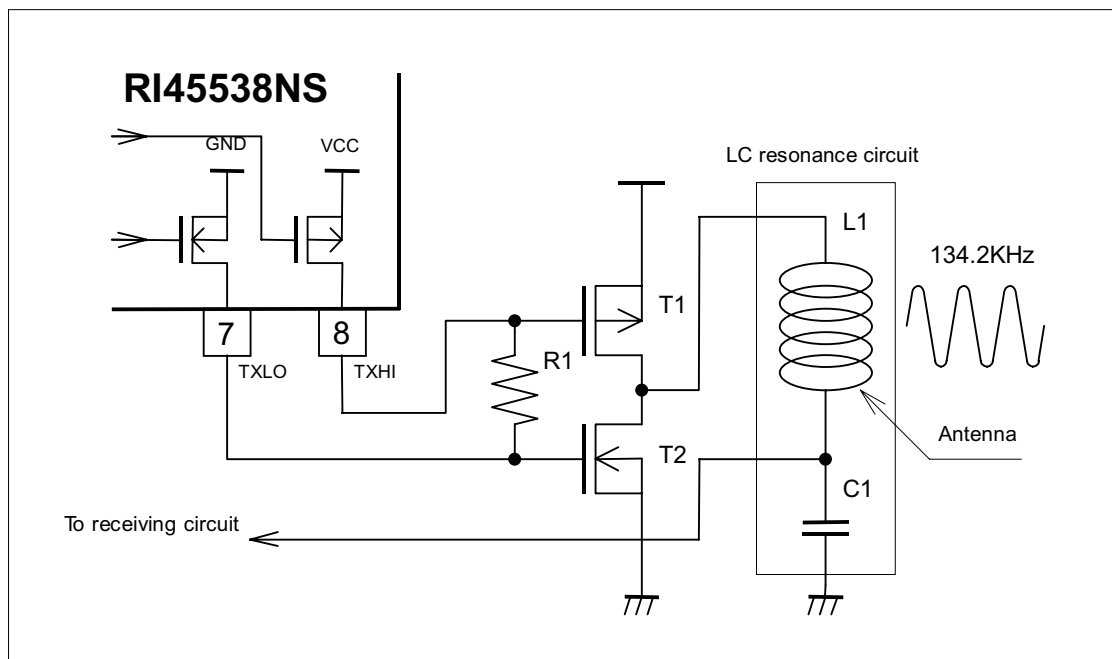


* When configuring an applied circuit, take the following into account:

- Choose the capacity of a resonance capacitor for clock generator oscillator in accordance with the oscillator characteristics.
- Define the frequency accuracy and variation of the clock generator oscillator by conversion based on the specifications for the **TIRIS** transponder to be used together so that it can be within the range of 17.17248 MHz to 17.18272 MHz (standard frequency: 17.1776 MHz).
- Select the values at resonance points around 134.2 kHz for L and C of the antenna circuit, respectively. (In the example illustrated above, the following combination is used: antenna: 48 μ H; capacitor: 0.03 μ F = 0.01 μ F \times 3 units)
- It is desirable to use a MOSFET having a low on-state resistance for antenna driver

11 Typical Transmitter Circuit Configuration

This RF-module IC is provided with "TXHI" and "TXLO" terminals which can drive external MOSFETs for driving the LC serial resonance antenna circuit. This resonance antenna circuit is to send 134.2-kHz signals to the remote **TIRIS** transponder. Use these terminals as illustrated below.

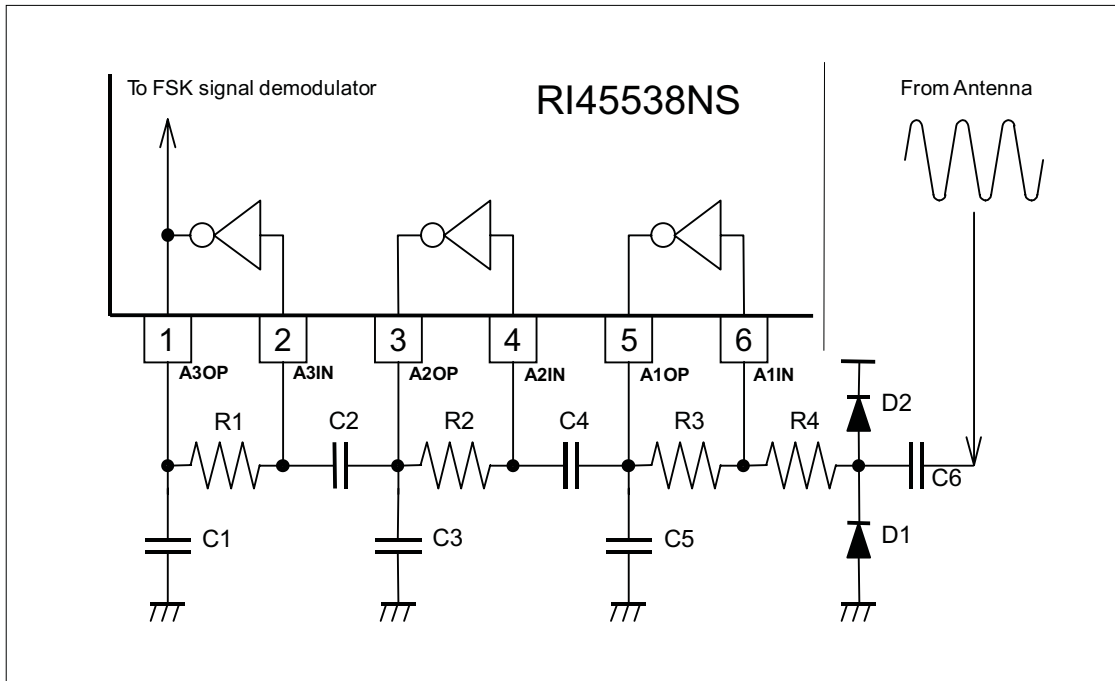


In this circuit configuration, by selecting a value for R1 within a range of several hundred ohms and in accordance with the characteristics of MOSFETs (T1 and T2) and introducing the selected value, the through current which is consumed by the MOSFETs themselves during transmission can be reduced. If the value for R1 is too high, the on-state resistances of T1 and T2 become very high and they will have difficulty in driving the LC resonance circuit, leading to a possible reduction of available data communication distance. Therefore, it is recommended that the value for R1 be defined after careful evaluation of the characteristics of T1 and T2.

L1 and C1 in the LC resonance circuit may be mutually exchanged in position without giving significant adverse effects to the operating performance of the circuit. However, the connection as is as illustrated above is most preferable since it reduces potential influence of high-voltage transmission signals produced at C1 on T1 and T2, thus a higher efficiency is gained.

12 Typical Receiver Circuit Configuration

Three simple CMOS inverter type amplifiers are integrated in this RF-module IC in order to amplify the FSK signals received from a remote **TIRIS** transponder up to a satisfactory logic level. The IC is designed so as to permit their amplification factor and frequency characteristics to be selected within a certain range by the use of appropriate external parts and/or circuits. A typical applied receiver circuit is illustrated below.



In general, the FSK signals sent from a remote **TIRIS** transponder are found within a band of 120 kHz to 140 kHz, mainly due to dispersion of workmanship during manufacture and ambient temperature fluctuation during transmitting operation. Therefore, by damping signals that fall out of the above band range as much as possible, noise suppression performance can be improved. In the illustrated circuit configuration, amplifier input coupling capacitors C2, C4 and C6 are used to reduce extremely low-frequency noise signals, and amplifier output load capacitors C1, C3 and C5 to reduce high-frequency noises. If you desire to enhance the noise resistance of the circuit still more, it is necessary to install a required number of external wide band amplifiers with high amplification factor and add an active band pass filter, LC resonance circuit, etc.

D1, D2 and R4 for input into the first amplifier (A1) form a circuit to prevent high-voltage signals for power transmission and similar signals from entering the IC, thereby keeping from occurrence of latch-up or other adverse situations. This circuit or otherwise, an equivalent protector, must be inserted without fail.

13 Typical Antenna Circuit Configuration

The antenna circuit consisting of L and C illustrated earlier in this manual (see the section describing “Applied Circuit Configuration – Example”) is designed to work as an LC serial resonance circuit in which impedance drops in the presence of resonance frequencies during sending operation, and as an LC parallel resonance circuit in which impedance increases in the presence of resonance frequencies during receiving operation. The relationship between L and C incorporated in the resonance circuit can be defined according to the following expression. Each value is calculated using this expression:

$$f_{(134.2\text{KHz})} = \frac{1}{2\pi\sqrt{LC}}$$

The higher the Q value (quality factor) is, the higher transmission power the antenna L obtains and also the higher the receiving gain becomes, thus allowing the system to have a greater available data communication distance. If, however, at switch-over from power transmission mode to the receiving mode, damping of the power transmission signal would not be completed before the remote **TIRIS** transponder sends its ID code back to the IC, the signals sent from the transponder could not be received properly. And the higher the Q value is, the longer the decay time of this power transmission signal will be. It has been revealed by experimental testing that an antenna with its maximum Q value of around 30 is usable in the circuit as is as illustrated in the “Applied Circuit Configuration – Example” section. If it is desired to use an antenna having a higher Q value, some measures must be devised and added to this circuit.

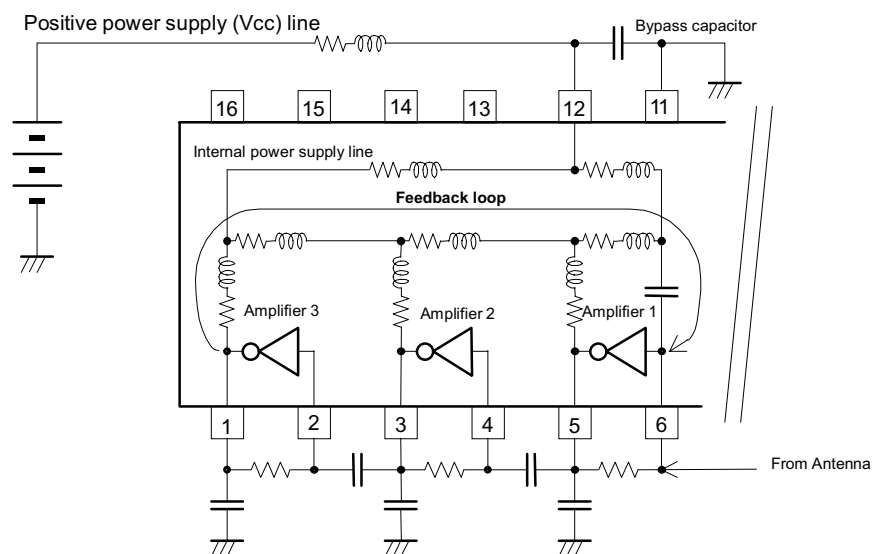
Additionally, the characteristics and efficiency of the resonance circuit used here greatly depend not only on the antenna L but also on the capacitor C and the MOSFETs which drive them. Therefore, the application of the lowest possible impedance at the frequency $f(134.2 \text{ kHz})$ to them will permit a higher transmission power, and as a result, it will allow the system to have a greater available data communication distance with the remote transponder.

14 Precautions for Mounting and Actual Use

Described in this section are the precautions to be taken at mounting and actual use of the RI-RFM-006A while designing and manufacturing a **TIRIS** Read-Write System using this IC, especially, critical issues as may affect the operating performance of the IC and, in particular, the system communication performance with a remote **TIRIS** transponder.

14.1 Power Supply Line

When the signals returned from a remote **TIRIS** transponder are amplified by sequentially using the three CMOS inverter type amplifiers incorporated in this RF-module IC, an undesirable feedback loop is formed from the third amplifier toward the first one through parasitic L, R and C whose formation is not avoidable because of the structure of this IC and its internal power supply line (see the diagram below) as CMOS devices are inevitably bi-directional. If this feedback loop is left as is, it normally leads to an oscillation; particularly, when the frequency band of each amplifier is limited so that it matches that of the transponder return signals, oscillation occurs at a frequency within this band which counts on high gains from the very nature of things, in consequence, adversely affecting the demodulating performance of the received FSK signals.



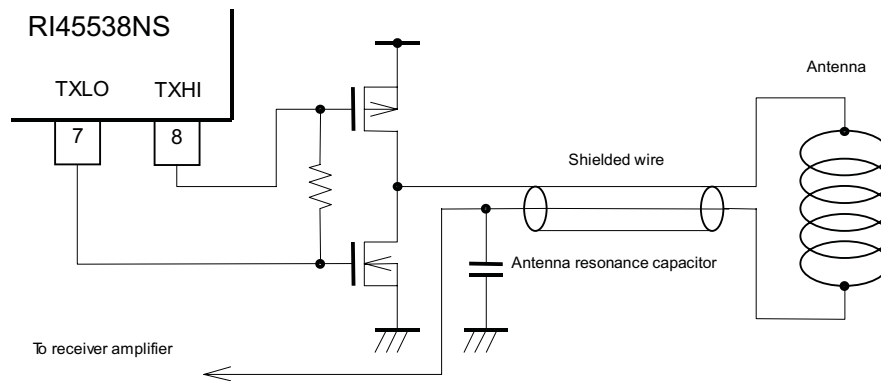
Equivalent circuit for internal power supply line feedback loop

This situation does not a little occur when a multiple number of high-gain amplifiers are integrated in a CMOS device. Formation of this undesirable feedback loop in the amplifier band can be avoided by minimizing the impedance of the power supply line through optimization of the printed circuit boards and using a suitable bypass capacitor. It is extremely difficult to obtain true values for these parasitic L, R and C forming the internal power supply line feedback loop, but it can be said from the empirical viewpoint that it is possible to inhibit the said oscillation using a bypass capacitor with a capacity of $1 \mu\text{F}$ and having a sufficiently low impedance within the said amplifier frequency band provided that appropriate wiring patterns are defined for the power supply line on the printed circuit boards and in the peripheries of external parts for the amplifiers.

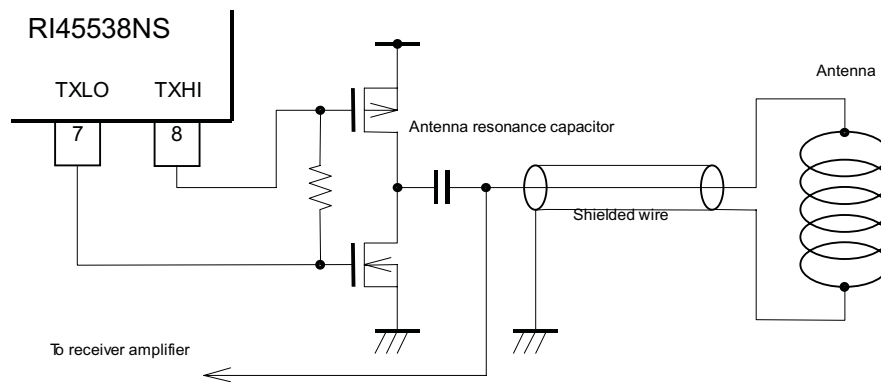
14.2 Wiring for Antenna Circuit

As previously described, the FSK signals sent from a remote **TIRIS** transponder are normally found within a band of 120 kHz to 140 kHz. Therefore, the signal receiving circuit of this **TIRIS** Transmitter- Receiver System is designed so that the signal amplification factor is necessarily highest within this band. Because of this, all signals and noises which are produced by other devices and whose frequencies fall within this band greatly affect the system performance, especially, its available data communication distance with the remote **TIRIS** transponder among others.

In the same way, they have quite the undesirable effect not only upon the environment in which the proper antenna for the system is found, but also upon the wire used to connect it with the IC's "A1IN" pin which works as the first-phase amplifier for received signals. Furthermore, if there are wires for square or pulse wave logic signals containing high-frequency components (even though their fundamental frequencies are low) very close to this antenna connection wire, the system's available data communication distance with the remote **TIRIS** transponder is further shortened due to the adverse effects of such wires. For all that, if there is no other alternative than to use a long wiring between the IC and its external antenna, it is suggested that a shielded wire be used for antenna wiring in either way as illustrated below. With this, the antenna wiring will be less susceptible to the aforementioned adverse effects.

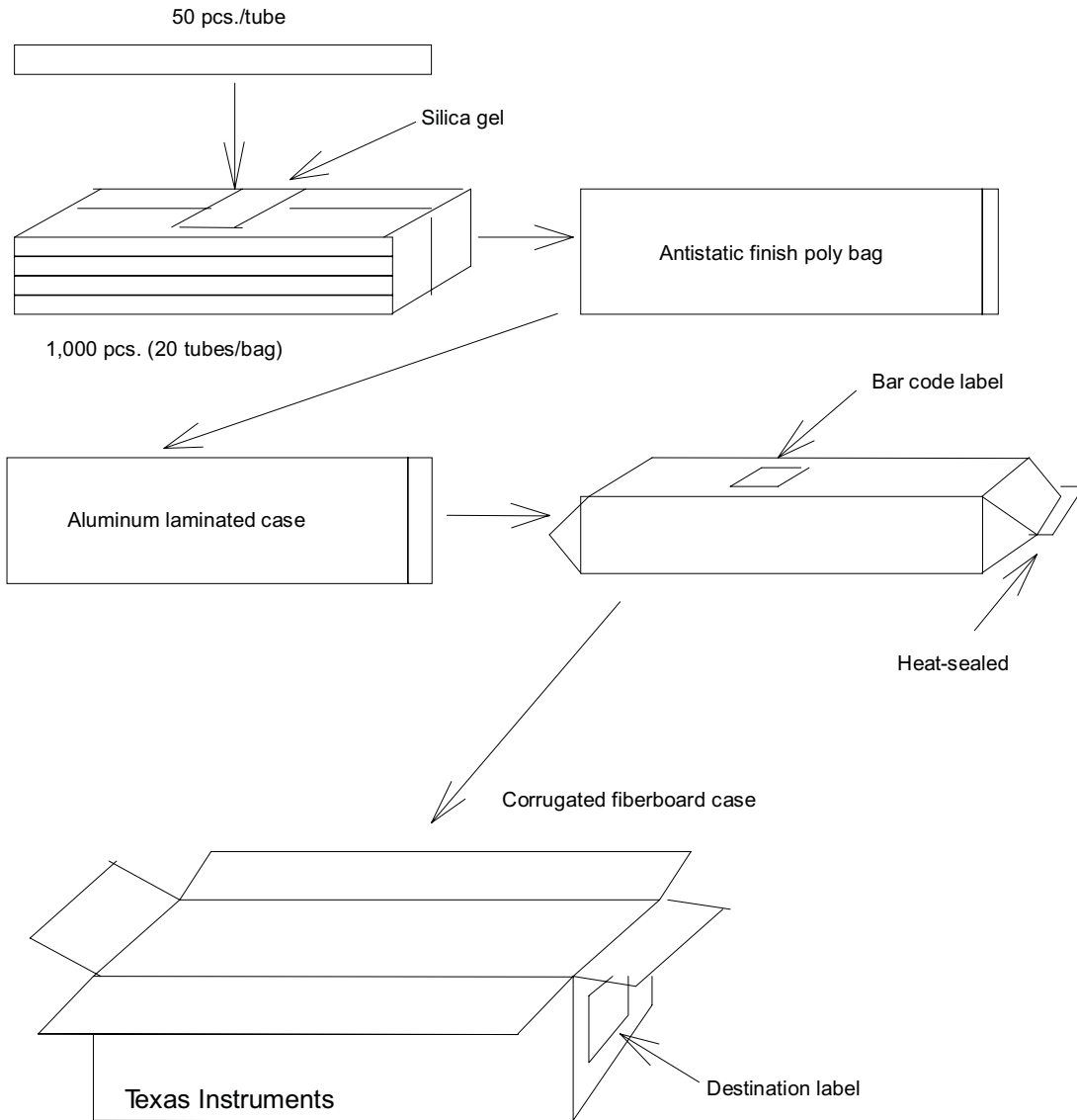


a. When the antenna is driven first.



b. When the capacitor is driven first.

15 Package



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