

PHONE REMOTE SYSTEM

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PHONE REMOTE SYSTEM APPLICATION NOTE

I - INTRODUCTION

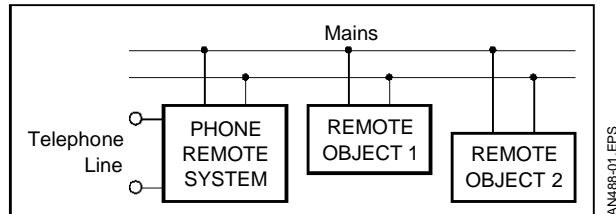
I.1 - General Purpose

In the Application Note AN535, we described how to implement the basis of a power line network using the dedicated modem chip ST7537CFN. This network has been validated with ST7537 MASTER & SLAVE systems, and shows the feasibility of power line control. But Home automation systems allow more than switching a light, or changing the value of a digit. The possibilities of the network increase each time we connect a new device on it. For instance, adding a phone remote system will allow the remote (from anywhere on the planet) control of devices connected on the network only by calling your house. The phone remote system is now demonstrating this fact : a telephone interface that allows the householder to give instructions to appliances from outside.

I.2 - Description

The phone remote system is a device connected to both telephone line and power line network. It is able to detect the phone ring, to hang up the line, and "converse" with the householder. This dialogue is done by using the DTMF (digital tone multi-frequency) generated by the remote phone. To answer back, the phone remote system is beeping. Of course, this is a low cost choice and the system can be improved by using a voice synthesiser with on line help and so on...

Figure 1 : Phone Remote System Connected to the Power Line Network



In a classical electric installation, this device would have used one control cable for each controlled object. With power line control, you just have to plug it and the link is done with all devices controlled by mains network.

I.3 - Improvements

The part II describes several improvements done to the communication program explained in AN535. These modifications allow new features :

- software carrier detect,
 - C.S.M.A. timings (Carrier Sense Multiple Access),
- and the use of communication modules in phone remote program.

II - POWER LINE COMMUNICATION USING ST7537CFN

The ST7537 CFN power line modem complies with the regulation described in the CENELEC EN50.065-.1 document, (so frequency, bit coding and other useful features are included in the chip). Nevertheless, the designer of an application has to take in account the power line communication specification when writing his protocol. For instance, access protocols are required for coexistence on the medium.

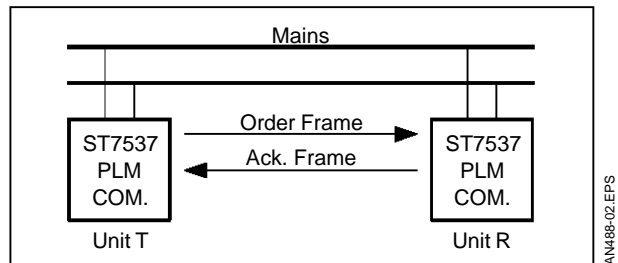
II.1 - C.S.M.A. Timings

The following paragraphs give a concrete case of communication on power line network. In first, only 2 devices are connected to the network. Then, others devices are connected, and we will be confronted to a real network specification.

Communication between 2 units

This is the simplest case of communication. Only two devices are able to send and receive packet on the network. One unit sends an order, the other one is replying with an acknowledge (see Figure 2).

Figure 2 : Two Units on the Mains



The unit T checks that the network is free for access thanks to the Carrier Detector, then it sends its frame and waits an acknowledge during a delay T_{wack} . The unit R receive a frame and sends an acknowledge if R is the destination of the frame. R must send the ack. frame before the end of T_{wack} . If it is not the case, or if T has not received the acknowledge, T tries again to send the order. Of course the frame format must allow error detection by the receiver (order checksum) and by the transmitter (checksum in ack. frame). In most of the case, communication occurs without error, and the both units must keep silent for a delay T_{silent} in order to leave time for application control. To allow the two units to transmit, the unit T has to wait more than R, so R will be the first to take the channel if it needs to transmit.

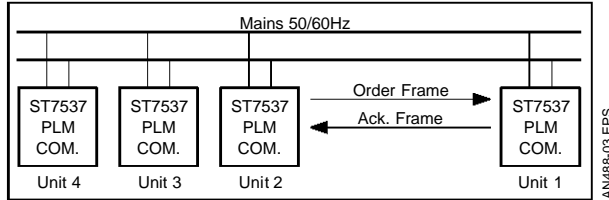
If the two units send a frame exactly at the same time, they will not receive ack. frame, so they will retry after a delay (T_{wack}). A random value is added

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to make one of the two unit faster than the other one. The total delay is $T_{retrans}$.

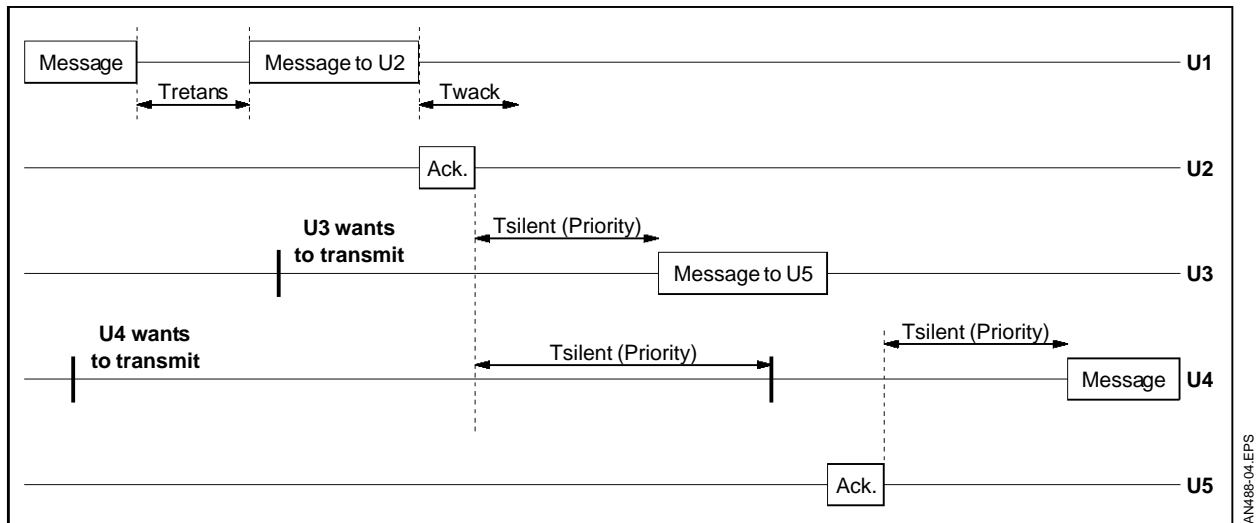
Communication with several units

Figure 3 : Several Units on the Mains



With several units, the timing is the same, but even if a unit is not concerned with a communication, it has to get the frames in account for timing control. For instance, it has to reload its time to keep silent. And if several units have reload there time to keep silent at the end of a communication, the values reloaded must be different to avoid conflicts on the next communication. Again, a random value is added to make timing different. Here is a data timing chart of the transmitted signal of the different units (see Figure 4). Anyway, all units must send there message in less than two seconds.

Figure 4 : Power Line Communication Data Timing



Timing control

All these timing are resumed in the Table 1.

Table 1 : C.S.M.A. Timing

Symbol	Description	Time	Comment
T_{max}	Total duration of transmission	2s	
	Maximum duration of transmission after Starting	1s	Feature included in ST7537CFN
$T_{silentR}$	Length to wait from the end of a remote transmission to initiate a transmission	85 .. 125ms	At least 7 values
T_{wack}	Acknowledge sent after	0 .. 30ms	
$T_{retransmit}$	Retry transmitting	30 .. 72ms	
$T_{silentT}$	Duration between two transmissions of the same device	125ms	

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In order to implement these timing, an easy way is to use a single timer and several registers corresponding to the different delays you want to count. The timer will decrease the registers at each overflow, and the counters are "launched" by loading a value in the corresponding register.

This access protocol allows an additional network priority: if you allow unit 1 (U1) to transmit before unit 2 (U2), then U1 will always sends its messages before U2, and so will have a highest network priority. By choosing the range of TsilentR of a unit, you will then choose its priority.

Table 2 : Priority According to TsilentR

Range	Priority
85 .. 94ms	Highest priority
95 .. 104ms	Standard priority
105 .. 115ms	Lowest priority

II.2 - Soft Carrier Detector

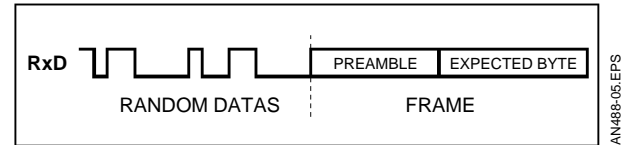
We have seen that by programming the TxD to "0" in receive mode we increase the sensitivity of the ST7537 because there is no more clamping by CD.

You will be able to have good communication with a receive signal of around 50dB μ V which means a dynamic of around 70dB.

Because we want to get the benefit of the very good sensitivity of the ST7537, we will program TxD to "0" in receive mode and create by soft a frame detector. We will use the CD signal as mentioned by CENELEC only when we want to transmit a frame. Different software frame detectors can be implemented depending of the resources of your microcontroller. You can program your microcon-

troller to go in receive frame when it received the expected byte.

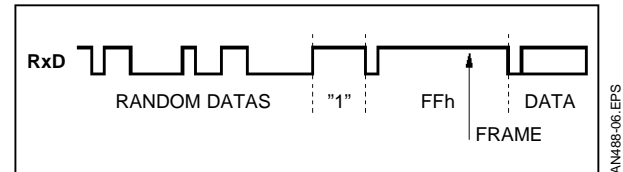
Figure 5 : RxD Data Timing



So the preamble is for demodulator training (when you start a communication the 3 first bits are lost by the receiver) and when you will match with expected byte the micro-controller will go in receive frame routine.

On the ST6 microcontroller we have implemented the following frame detector.

Figure 6 : Preamble Detector



We put TxD = "1" on the transmitter for around 4ms (for demodulator training) and after we send in asynchronous mode FFh following by the complete frame. On the receiver, we check that we have RxD equal to "1" for at least 7ms (we are looking for FFh), then we go in receive and we will have frame synchronisation on the first start bit of the data.

We did a trial in our lab with this system during 2 hours without having the ST6 going in frame receive routine on bad datas due to noise signal.

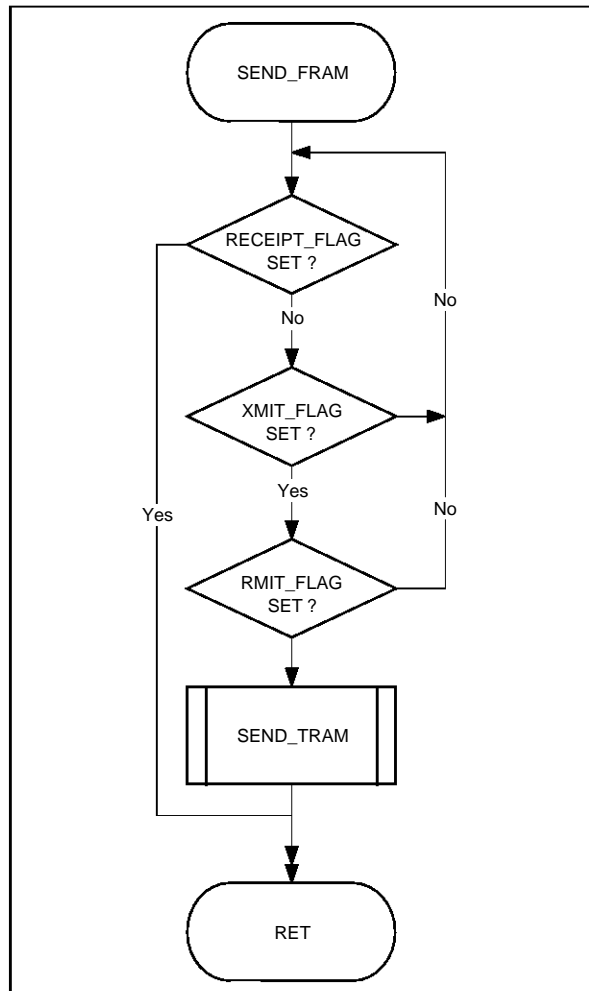
II.3- Implementation on ST6265

The C.S.M.A. (Carrier Sense Multiple Access) needs a Timer for its implementation. But the ST6265 timer 1 is already used for bit time and software carrier detect. Furthermore, sometimes the timer has several functions at the same time, so the timer programming becomes very complicated.

In order to simplify this programming, we have implemented a single time delay corresponding to bit time ($f = 1200\text{Hz}$). So for each mode there is a counter corresponding to a delay. The counters are incremented (or decremented) in the timer interrupt routine while they are cleared (or affected with values) in main program. For C.S.M.A. specifications, we use two counters :

- Xmit_count : This is the delay before retransmitting,
- Rmit_count : This is the delay before transmitting after a reception.

Figure 7 : Sending a Frame After C.S.M.A. Delays



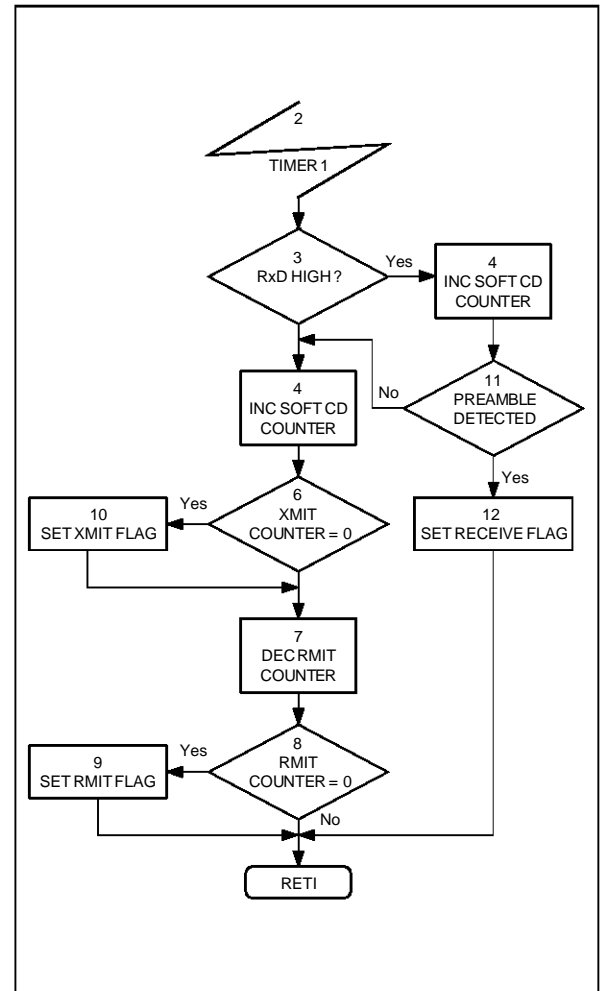
These counters are decremented in Timer 1 interrupt routine and flags are set when they become null. These flags are allowing the sending of a frame. Acknowledge frames are not concerned with these timing.

The timer will allow the sending of a frame after C.S.M.A. delays (see Figure 7).

With this way of programming, the places where counters are loaded are very significant (see Figure 8) :

- Xmit_count is loaded at the end of the message sending procedure in order to wait an acknowledge (30ms) and at the end of the reception of a good acknowledge (time between two transmissions of the same device : 125ms),
- Rmit_count is loaded at the end of a reception with a random value (time between two transmission of different devices : 85 to 115ms).

Figure 8 : Timer 1 Flow Chart



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III - PHONE REMOTE SYSTEM

III.1 - General Description

The phone remote system is using the ST7537CFN chip and its line interface for power line communication (see Figure 9). The control unit is ST6265 microcontroller (SGS-THOMSON) that has several functions.

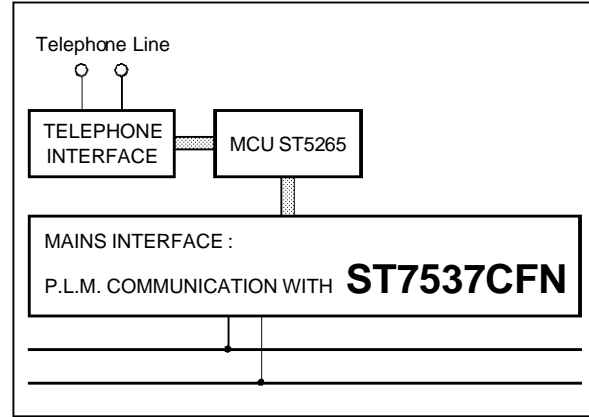
The telephone interface is described in further detail in next paragraph. The MCU mains functions are :

- detect a ring,
- take the line and hang up,
- decode DTMF code,
- make some "beep",
- control the modem chip,
- display its status (leds for instance).

These functions are the minimum required to pro-

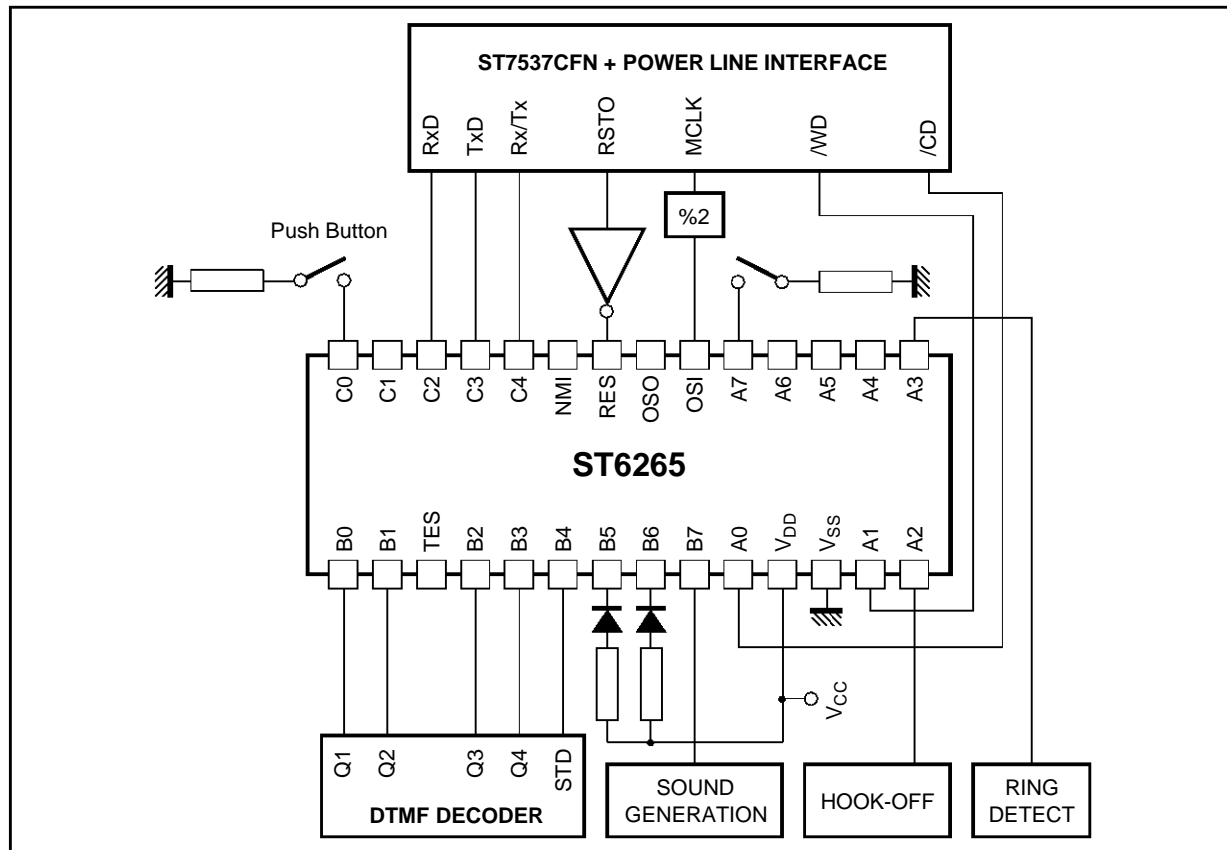
vide remote control. The Figure 10 propose these functions.

Figure 9 : Block Diagram



AN488-09.EPS

Figure 10 : ST6265 Application



AN488-10.EPS

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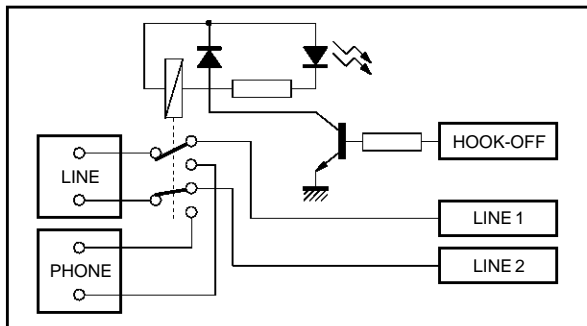
ST7537 interface

The ST6265 is directly connected to ST7537, excepted the clock that must be divided by a factor 2 (ST6265 is validated at 8MHz max. and ST7537 provides a 11MHz clock signal). For further details, refer to AN535.

Hook-off

The hook-off system must be able to take the line. A relay connected to the two wires of the telephone line complies with all regulations. See telephone interface part for more information.

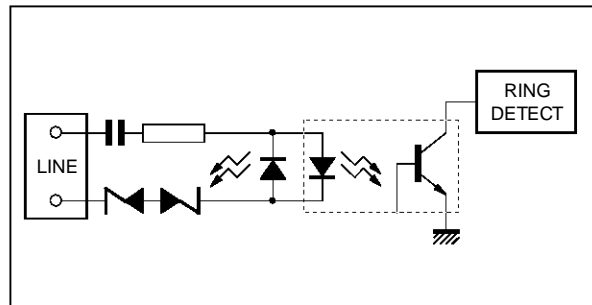
Figure 11 : Hook-off Schematic



Ring Detect

An opto-transistor is used to detect the ring signal on the line. So the system is isolated from the line and the microcontroller receive a 0 to 5V signal.

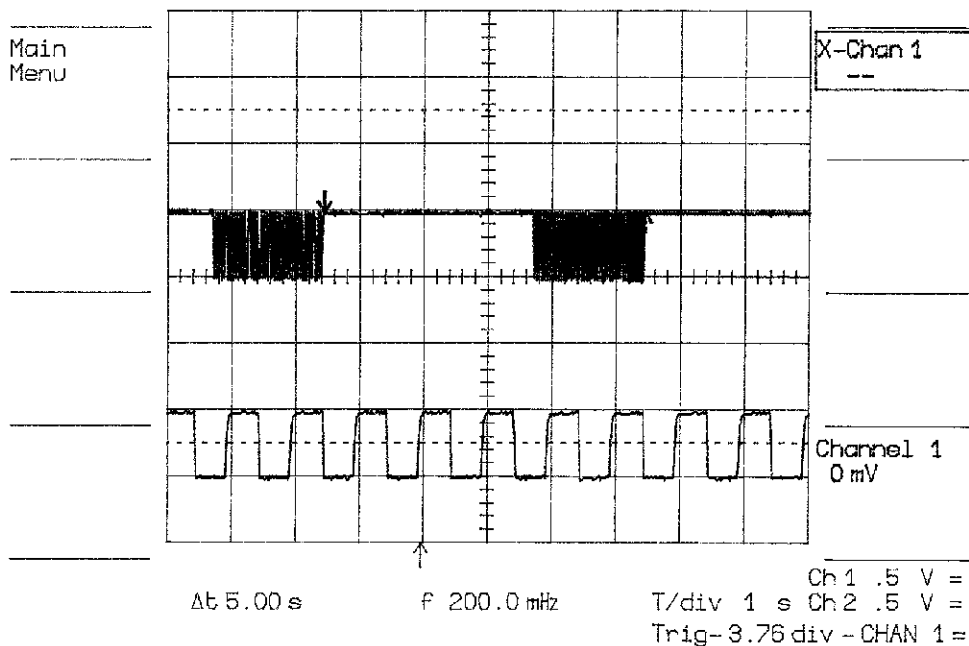
Figure 12 : Ring Detect Schematic



For example, this is what appears on ring detect pin with a French standard line (see Figure 13).

The first line is the ring detect signal which is zoomed on the second line. On French lines, the ring is about 1.5 second and the silence is about 3.5 second. That means a ring period of 5 seconds.

Figure 13 : Ring Detect Signal & Ring Detect Signal Zoomed

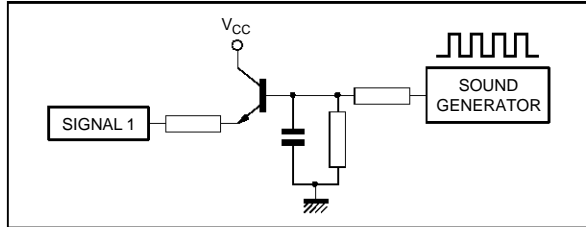


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Sound Generation

Sound generation allows reply from the system. MCU just sends square signal that makes a beep.

Figure 14 : Sound Generation Schematic

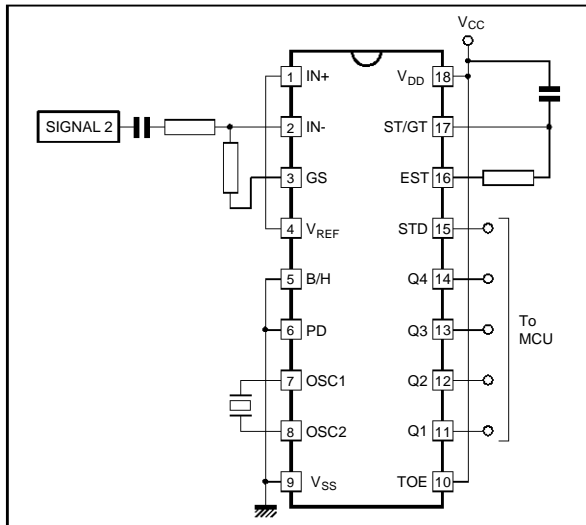


AN488-14.EPS

DTMF Decoder

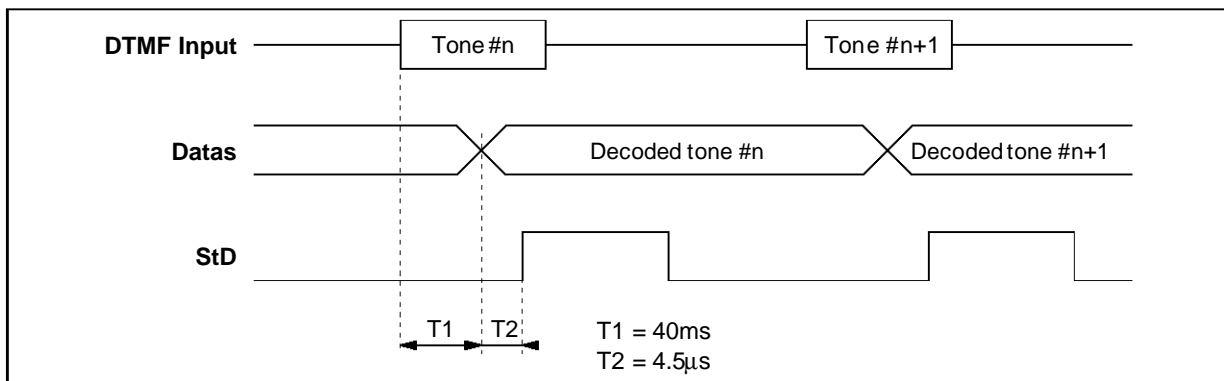
Users send orders with DTMF code. These codes are decoded with a DTMF receiver LC7385 (SANYO). It is configured in single ended input. It has a dynamic range input of 29dBm.

Figure 15 : Single Ended Input Configuration



AN488-15.EPS

Figure 16 : DTMF Receiver Timing Diagram



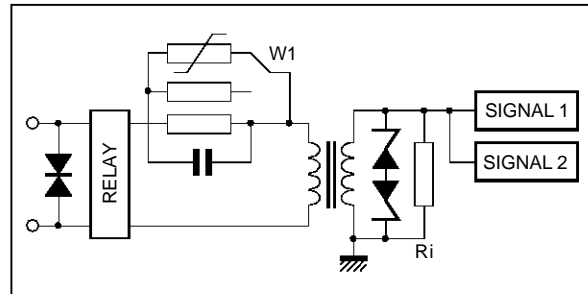
AN488-16.EPS

When receiving DTMF code, this IC chip is generating the following signal (see Figure 16).

III.2 - Telephone Line Interface

The line interface must verify regulation of system connected to telephone line, that's why it is described in detail here. Line interface input impedance and current consumption has been adjusted. In the following schematic, the transformer accept continuous current and current consumption is done by a resistor and a capacitor in parallel.

Figure 17 : Telephone Line Interface



AN488-17.EPS

III.2.1- Isolation

As the phone remote system is connected to the telephone line, it must be isolated from high voltages that may occurs on it. There are two connections to the line :

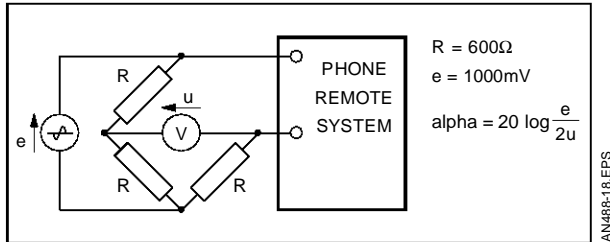
- the ring detect interface is isolated with an opto-transistor,
- the DTMF & sound generation interface isolation is made by a transformer and a voltage limitation by zener diodes.

Furthermore, a transil diode between the two line wires limits the input voltage.

III.2.2 - Input Impedance

The input impedance has been adjusted by changing Ri value (see Figure 17) with a Wheastone's bridge method explained in the Figure 18.

Figure 18 : Wheastone Bridge



e is generated by a HP3325B generator and u is read on a Fluke 45 controller. We made e scanning frequency from 300 to 4000Hz. The maximum values for u are shown in the Table 3.

Table 3 : Error Voltage versus Ri

Ri (Ω)	u (mV)	Ri (Ω)	u (mV)	Ri (Ω)	u (mV)
200	69	325	40	400	47
275	44	350	41	500	63
300	40	375	45	600	75

Ri has been fixed at 300Ω. That mean an adapting coefficient (alpha) :

$$\alpha = 20 \log \frac{1}{2 \cdot 0.04} = 21\text{dBm}$$

French standard specifies a value superior to 14dBm.

Figure 20 : Hook-off Between Two Rings

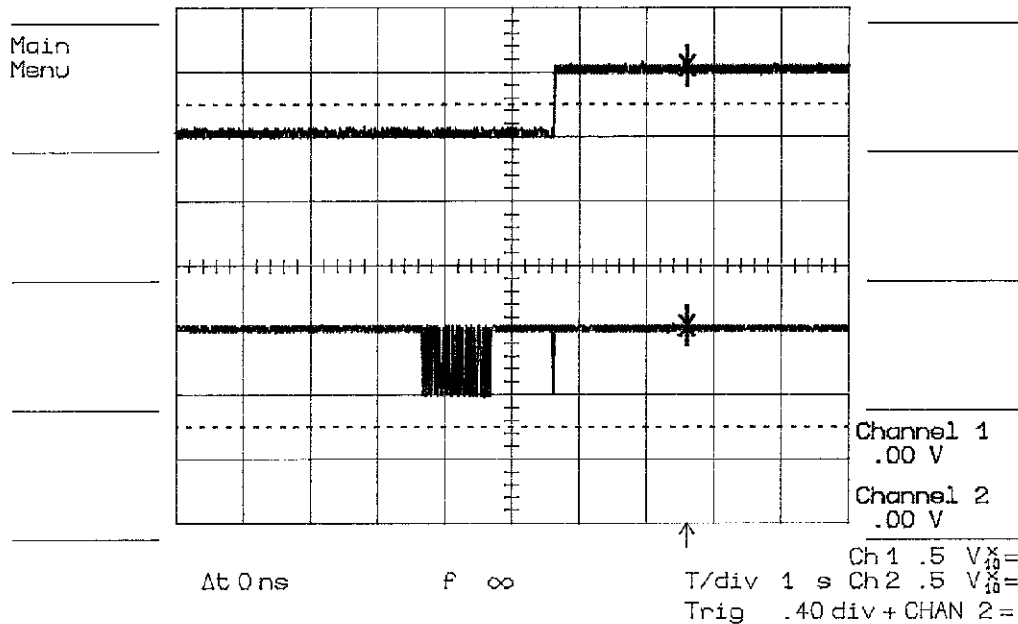
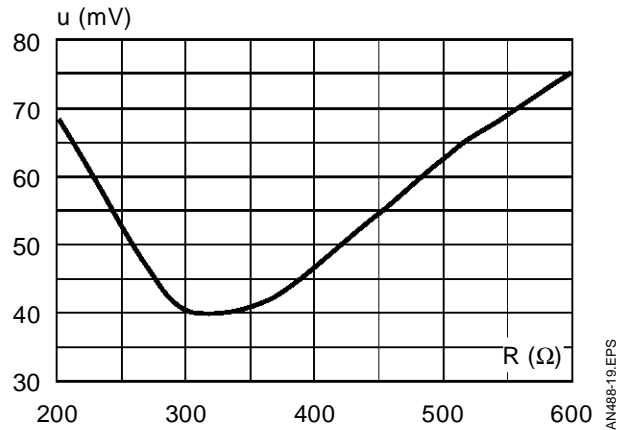


Figure 19 : Error Voltage Versus Ri



III.2.3 - Current Regulation

Line current regulation is not needed in several countries. For these countries, a strap allows to disable current regulation which is done by a CTP resistor.

III.2.4 - Hook-off Procedure

When taking the line, the system must care of the ring train. If it takes the line when phone is ringing, the relay will switch a voltage superior to 70 Volts. To avoid this, the best way is to wait a silence (no ring). The phone remote system is waiting the end of a ring to take the line, as shown in the Figure 20. The first line is the relay command and the second line is the ring signal.

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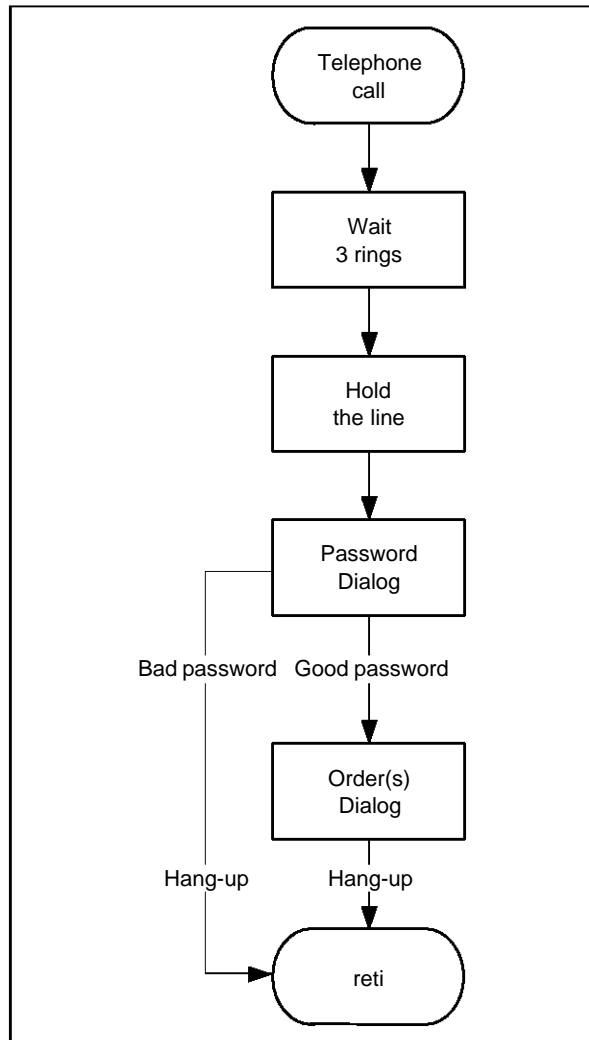
III.3 - Mains Flow

The phone remote system has a very simple progress. It only has to wait after a ring, count for a pre-defined number of rings, take the line, ask for a password, and then send the user's orders on the

power line network (see Figure 21).

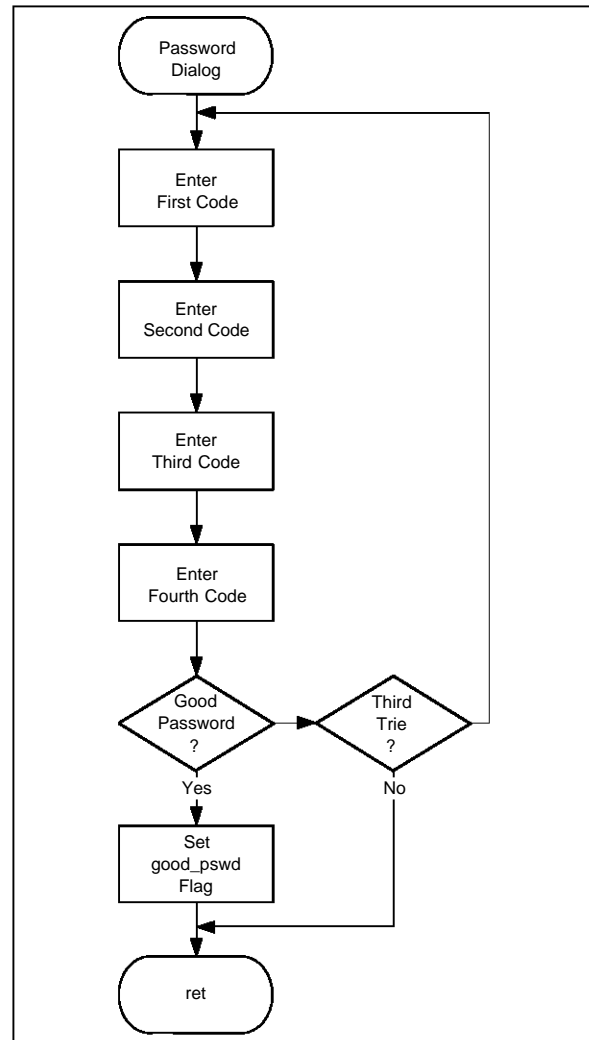
For security reasons, the user has only three tries to enter his password. If this operation is successful, he is allowed to send orders, otherwise the system hangs up (see Figures 22 and 23).

Figure 21 : Phone Program Main Flow



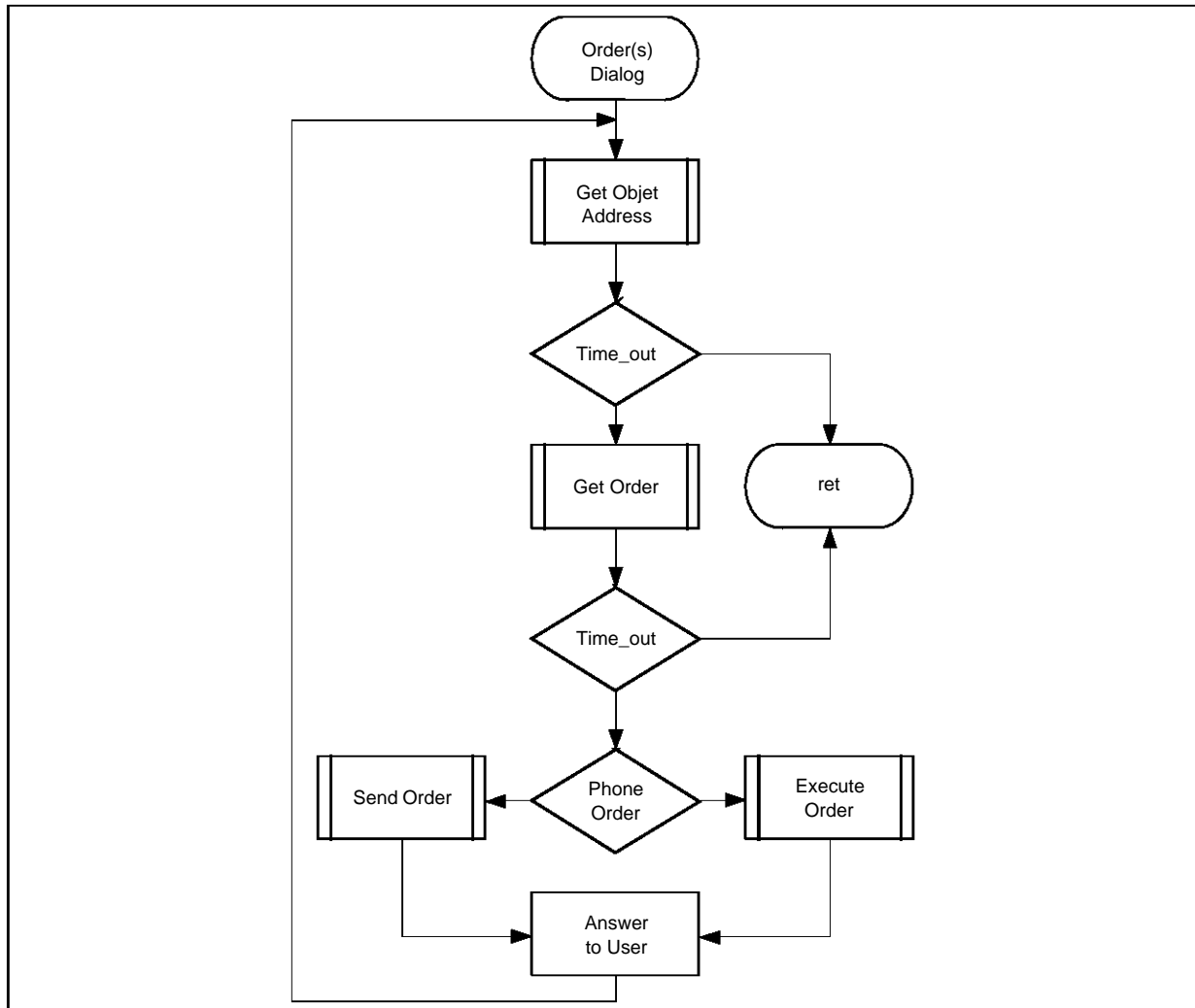
AN488-21.EPS

Figure 22 : Password Dialogue



AN488-22.EPS

Figure 23 : Orders Dialogue



AN486-23.EPS

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III.4 - Application Procedure

This part describes installation and utilisation of the phone remote system.

III.4.1 - Installation

The phone remote system needs to be connected to the mains and to the telephone line.

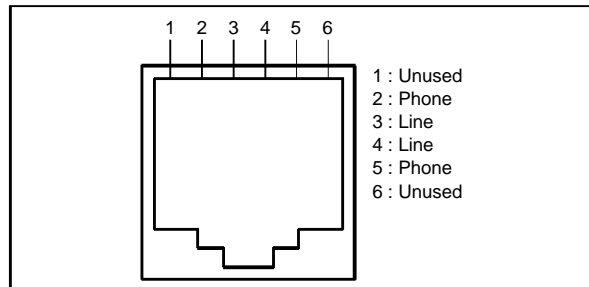
Connecting to mains :

Before connecting the phone remote system to mains, verify that the selected voltage is the same as your mains installation. The default voltage is 220 Volts/50Hz.

Connecting to telephone line :

The telephone line connector is a RJ11 type. This connector is wired according to French specifications.

Figure 24 : RJ11 Connector



III.4.2 - Description

The phone remote system owns several switches and LEDs that indicate status and allow the configuration of parameters as number of rings, confidential code, ...

Table 4 : Parts Description

Part	Description
Switch	User for switch the device ON/OFF
Mini switch	User to select the delay before hook-off : 3 or 5 rings
Push button	User to reinitialize the status LEDs (single push) or to reinitialize the protection code (3 seconds push)
Red LED (L1)	Violation LED (wrong code)
Green LED (L3)	Hook-off LED
Yellow LED (L4)	Ring LED
Orange LED (L2)	Bad power line network address : no acknowledge

III.4.3 - Use

Enter Confidential Code

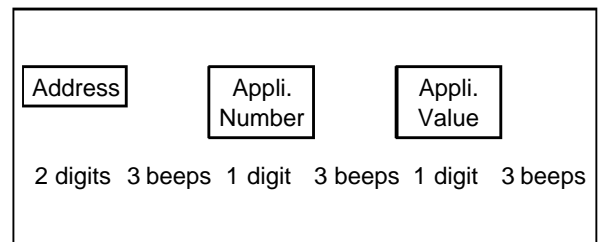
When calling the phone remote system, you have to wait three or five rings. Then the system hooks off and beeps three times. You have twenty seconds to enter the confidential code by using your

phone keyboard. Only DTMF phones are supported. The initial value of the code is 0000, but of course you can change it. If the code entered is the good one, you are allowed to give orders. Otherwise, you have two other attempts.

Enter Orders

An order is an object address (two digits), an application number (one digit) and a value (one digit). After you have entered the object address, you hear three beeps (or you have to retry). Then you enter the application number, and you hear three more beeps. At last, you enter the application value. If you hear three beeps, that means the message has been sent and that an acknowledge has been received. Then you are allowed to send an other order.

Figure 25 : Address Format



The slave systems have address values from 00 to 15. For these systems the application number select the dimmer (number 1) or the digit (number 2). The value is the number displayed on the digit, or the light intensity. For instance :

- "15,2,0" will display 0 on the slave system with address is 15,
- "13,1,9" will switch the light on slave system number 13 on.

There are special orders for phone control :

- if you enter "99,1", then the system will beep you the confidential code. If the code is 3456, you will hear 3 beeps then four, then five and then six beeps,
- if you enter "99,2", and four digits, these four digits will be the new confidential code to use for further call.

Table 5 : Allowed Orders

Enter	Values	Action
XX,Y,Z	$00 \leq XX \leq 15$ $0 \leq Z \leq 9$	Y = 1 Light intensity = Z Y = 2 Display value = Z
99,1		Beeps the confidential code
99,2,XXXX	$0000 \leq XXXX \leq 9999$	New value for confidential code

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Local Configuration

The yellow LED is lighting when "the phone is ringing". After 3 or 5 rings (depending on mini-switch), the system takes the line, and the green LED remains on during all the phone dialogue. If three bad codes are sent, the red LED will switch on. If a power line communication error occurs, the Orange LED will light. The red and the orange LED will be left on, so a single push on the push-button will switch these LED off.

If you push on the push-button for more than 3 seconds, the confidential code will be changed to 0000. The confidential code is stocked in EEPROM and will remain even if you disconnect mains.

IV - CONCLUSION

The phone remote system increases the facilities offered by your automation network. With this sys-

tem you can send orders by using DTMF code. By using a memory phone or a pocket dialler, you would be able to send orders only by choosing the system you want to talk to. For instance, you push the button called "heating on" and the order is immediately sent to the heater. Furthermore, you could select an other temperature for the heating system, or ask for the temperature in any room of your house. These improvements are possible by adding a voice generator (SGS-THOMSON has dedicated voice chips) and if temperature sensor and heater are connected to the network. The phone remote system detailed in this note has not all these facilities, but it is a very low cost application with only few components and low cost choice for MCU and phone interface. The ST7537 is providing the power line communication and a hardware watchdog, while leaving resources for a low cost microcontroller.

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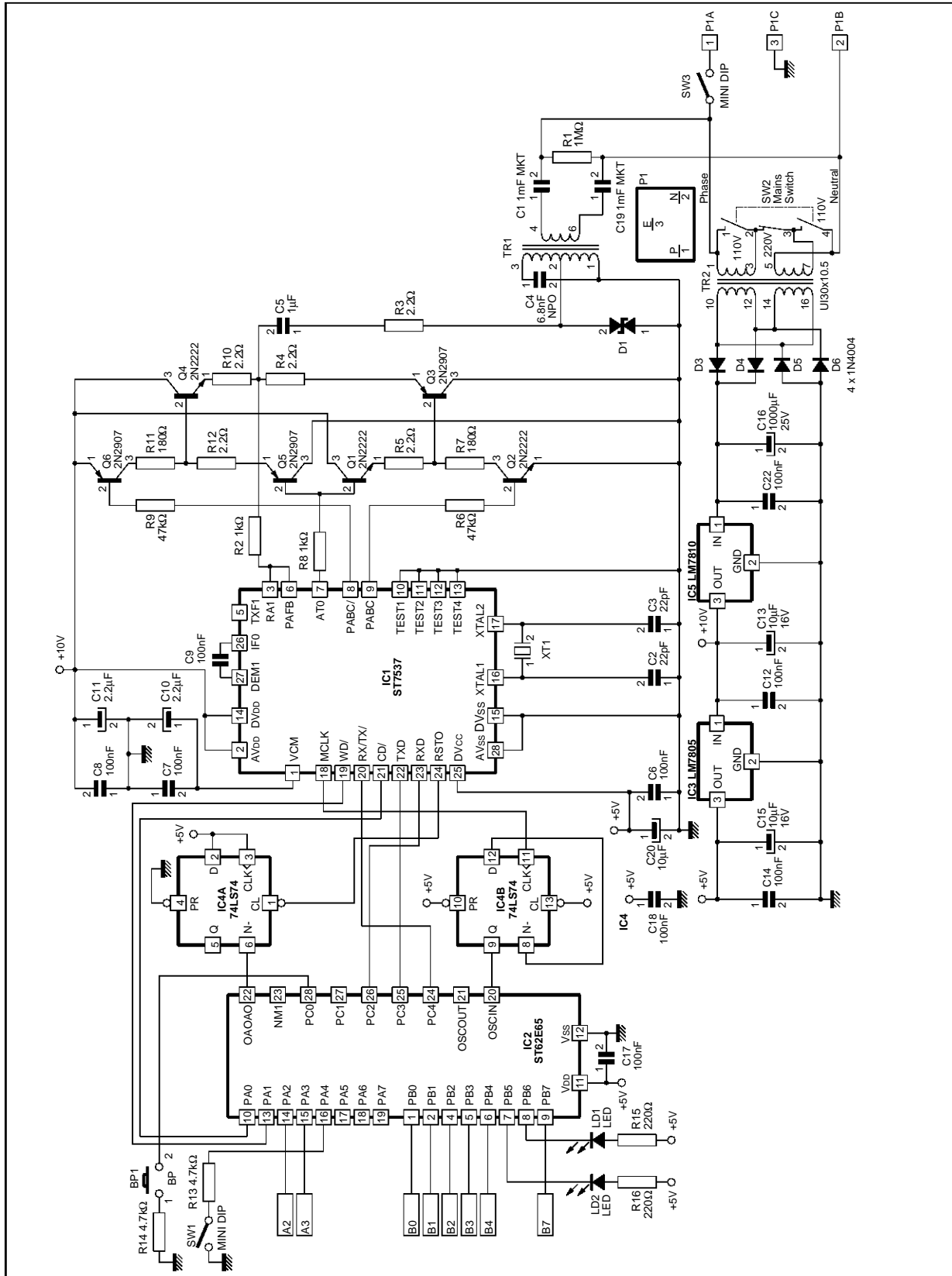
V - ANNEXE 1 : BILL OF MATERIALS

Designation	Value	Package
BP1	BP	BP
C1	1mF	CAPC4
C2	22pF	CAPD4
C3	22pF	CAPD4
C4	6.8nF	CAPD4
C5	1μF	CAPC4
C6	100nF	CAPD4
C7	100nF	CAPD4
C8	100nF	CAPD4
C9	100nF	CAPD4
C10	2.2μF	CAPC4
C11	2.2μF	CAPC4
C12	100nF	CAPD4
C13	10μF	CAPC4
C14	100nF	CAPD4
C15	10μF	CAPC4
C16	1000μF	CAP12
C17	100nF	CAPD4
C18	100nF	CAPD4
C19	1mF	CAPC4
C20	10μF	CAPC4
C22	100nF	CAPD4
C23	2.2mF	CAPC4
C24	100nF	CAPD4
C25	100nF	CAPD4
C26	100nF	CAPD4
C27	100nF	CAPD4
C28	470nF	CAPD4
D1	Diode	DIODE
D2	Diode	TRANSIL
D3	1N4004	DIDB8
D4	1N4004	DIDB8
D5	1N4004	DIDB8
D6	1N4004	DIDB8
D7	1N4148	DIDA8
D8	ZEN.4.7V	DIDA8
D9	ZEN.4.7V	DIDA8
D10	ZEN.15V	DIDA8
D11	ZEN.15V	DIDA8
G1	GEMOV	GEMOV
IC1	ST7537	ST7537
IC2	ST62E65	ST62E65
IC3	LM7805	BTO220
IC4	74LS74	DIL14
IC5	LM7810	BTO220
IC6	LC6385	DIL18
IC8	4N36	DIL6
K1	RELAY_DPDT	RELAY
LD1	LED	LED
LD2	LED	LED

Designation	Value	Package
LD3	LED_JAUNE	LED
LD4	LED_VERTE	LED
P1	ALIM220V	ALIM220V
P2	RJ11	RJ11
Q1	2N2222	BTO922
Q2	2N2222	BTO922
Q3	2N2907	BTO5
Q4	2N2222	BTO922
Q5	2N2907	BTO5
Q6	2N2907	BTO5
Q7	BC547	BTO5
Q8	BC547	BTO5
R1	1mΩ	RES8
R2	1kΩ	RES8
R3	2.2Ω	RES8
R4	2.2Ω	RES8
R5	2.2Ω	RES8
R6	47kΩ	RES8
R7	180Ω	RES8
R8	1kΩ	RES8
R9	47kΩ	RES8
R10	2.2Ω	RES8
R11	180Ω	RES8
R12	2.2Ω	RES8
R13	4.7kΩ	RES8
R14	4.7kΩ	RES8
R15	220Ω	RES8
R16	220Ω	RES8
R17	470Ω 3W	RES14
R18	1.5kΩ 1W	RES12
R19	300Ω	RES8
R20	100kΩ	RES8
R21	100kΩ	RES8
R22	560Ω	RES8
R23	2.2kΩ	RES8
R24	4.7kΩ	RES8
R25	300kΩ	RES8
R26	220Ω	RES8
R27	4.7kΩ	RES8
R28	10kΩ	RES8
R29	100kΩ	RES8
SW1	MINI_DIP	SMINI
SW2	COMMUT	COMMUT
SW3	MINI_DIP	MINI
TR1	TOKO	TOKO
TR2	UI30X10.5	UI30X10.5
TR3	TR3	TRANSFO CECLA
W2	STRAP_3PTS	STRAP
XT1	CRYSTAL	CRYSTAL
XT2	3.57945MHz	HC49U

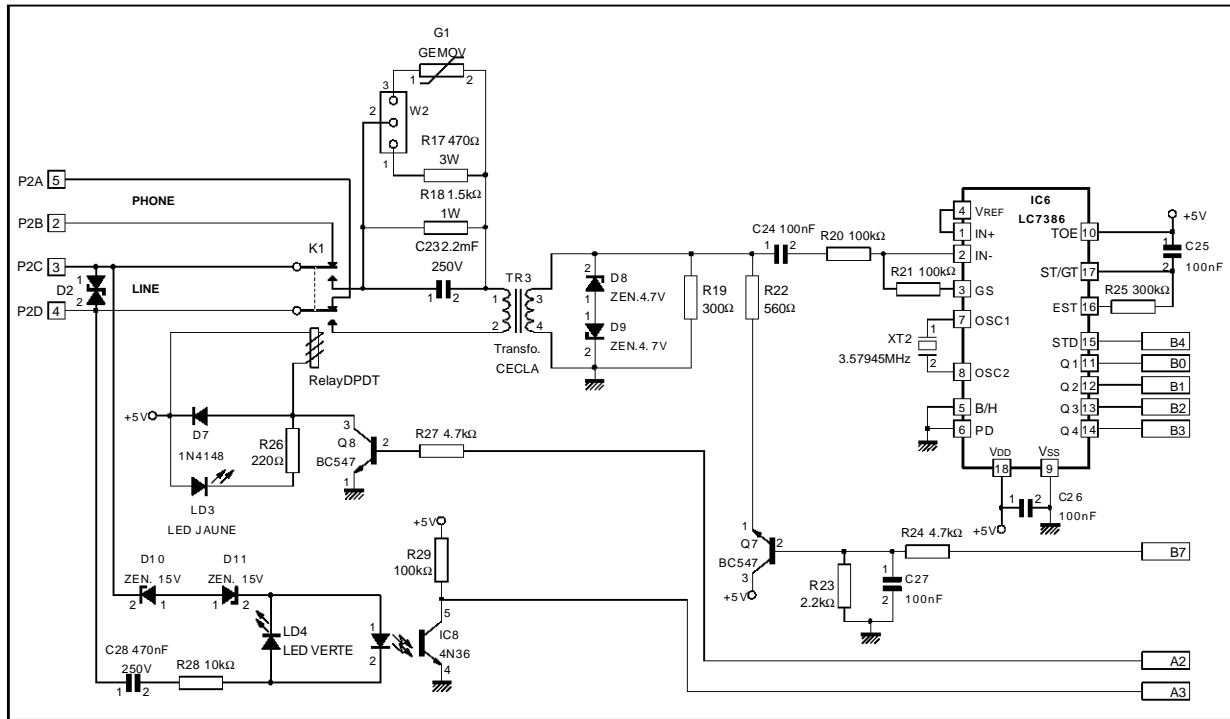
PHONE REMOTE SYSTEM APPLICATION NOTE

VI - ANNEXE 2 : SCHEMATICS



AN488-26-EPS

PHONE REMOTE SYSTEM APPLICATION NOTE



AN488-27.EPS

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