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A Design Of Prepaid Electricity Credit Recharge System Based On Dual Tone Multiple Frequency

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microcontroller

ABSTRACT

In an effort to improve the efficiency and ease of prepaid electricity top-up, Dual Tone Multiple Frequency (DTMF) technology offers an innovative solution that allows users to top up electricity via telephone. This study aims to design and implement a prepaid electricity top-up system that uses DTMF technology as an input method. The research methodology includes hardware and software design consisting of several main components, namely a DTMF module, microcontroller, and communication module. The DTMF module is used to detect and convert dual tone signals from the telephone into digital data that can be processed by the microcontroller. The microcontroller then processes this data to control the prepaid electricity meter top-up process. The system development stage begins with the selection and configuration of the appropriate DTMF module, followed by microcontroller programming to identify the DTMF code sent by the user. The system also includes a verification mechanism to ensure that the code entered is valid and secure. After verification, the microcontroller sends a command to the prepaid electricity meter to top up the credit according to the amount entered. The test results show that the DTMF-based prepaid electricity top-up system functions well, is able to recognize DTMF codes with high accuracy, and performs top-ups efficiently. This system offers ease of use for prepaid electricity customers, eliminates the need to go to a physical credit sales location, and allows top-ups from anywhere using a telephone. The conclusion of this study is that the DTMF-based prepaid electricity top-up system is a reliable and effective solution to improve convenience and efficiency for prepaid electricity users. Further implementation can be focused on improving security and integration with digital payment systems to provide a more comprehensive solution.

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INTRODUCTION

The prepaid electricity top-up system is one of the key elements in ensuring easy and efficient access for electricity consumers. Prepaid electricity has become a popular choice because it allows users to control and manage their electricity usage more flexibly. In order to improve user comfort and convenience, the design of a prepaid electricity top-up system based on Dual Tone Multiple Frequency (DTMF) is considered an innovative solution. Where in the digital era like today, prepaid electricity is a popular choice in managing electricity usage in households. The use of a prepaid system provides consumers with the flexibility to control their electricity usage more flexibly, as well as providing convenience in topping up credit. In an effort to continue to improve comfort and efficiency in electricity usage, the design of a prepaid electricity top-up system based on Dual Tone Multiple Frequency (DTMF) is an interesting innovative step to explore. The use of DTMF, which is commonly known as the sound or tone produced when pressing a button on a telephone, opens up opportunities to optimize the credit top-up process. This can provide a faster, more efficient, and more accessible solution for most commonly used mobile phones. Given the rapid development of technology, the implementation of a DTMF-based credit top-up system is expected to provide a positive contribution to user convenience and efficiency of prepaid electricity services. Currently, obstacles in prepaid electricity top-up are often related to the speed and accuracy of the top-up process. The use of faster and more efficient top-up methods can help improve user satisfaction and ensure better availability of electricity. Therefore, through the design of a DTMF-based prepaid electricity top-up system, it is expected to provide innovative solutions and provide a better user experience in managing prepaid electricity usage.

Technological developments provide benefits to human life in everyday life. With advances in technology, many equipment has been shifted from manual to automatic. Manual equipment has shortcomings in terms of speed, accuracy and accuracy, so that manual equipment can no longer be relied on and is starting to be switched to more automatic equipment. For example, in measuring electrical power, to find out how many kWh are used, a human must record them continuously. To overcome this inefficiency, the authors tried to design a digital KWh meter for an automated application for recording electrical power usage. This tool is able to display the amount of electrical power used, the remaining credit/power and the voucher pin number that has been entered. Apart from that, this tool has several advantages, namely that it uses communication with the DTMF (Dual Tone Multiple Frequency) system and the power and credit charging values can be used using the internet system. This system is a development of an existing kwh meter, only this system optimizes the use of the 89C51 microcontroller which is already common on the market.

Literature Review

Hardware Design

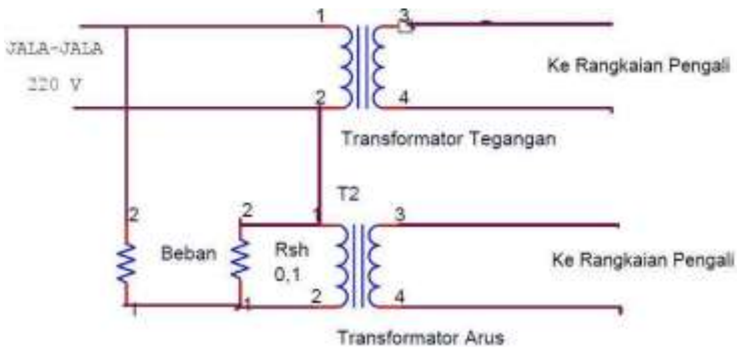

Figure 1. Voltage and current detector circuit (Source: M. Nurul Hudha)

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The main component of the voltage detector in the form of a transformer will change the PLN line voltage so that it can be fed to the multiplier circuit. The transformer functions as a step down transformer. The PLN 220 Volt AC line voltage will be reduced to a certain level so that it can be used as an input voltage parameter (V) in the multiplier circuit.

The current parameter (I) is obtained by passing the current flowing through the secondary coil of the transformer. Every change in load will cause a change in the current flowing in the secondary coil. With electromagnetic induction, changes in current in the secondary coil will cause changes in voltage in the primary coil. The voltage level in the output coil can be limited by providing a series resistance (shunt resistor) in the input coil.

Multiplier Circuit

The output signal from the voltage detector and current detector is fed to the multiplier circuit A5. The brain of the multiplier is the OTA 13600 or 13700. The OTA amplifies the differential voltage applied at the input (pins 13 and 14) and produces current at the output (pin 12). The gain factor is expressed in mA/V and is referred to as transconductance (gm). The slope of this transconductance is relatively linear and changes as a function of the current (steering) flowing at pin 16. So OTA amplifies two variables and amplifies the current as a product. Here one variable is the voltage tapped from the network and converted into driving current by P2 and R16. And the second variable is the voltage produced by the load current via R4. The OTA 13600 circuit as a voltage multiplier is shown in Figure 2.

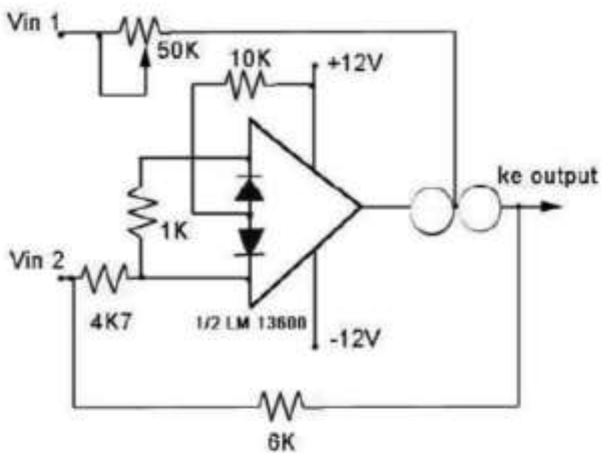

Figure 2. OTA 13600 circuit as a multiplier.

Reversing Buffer

This circuit is composed of an LM 741 operational amplifier. The Buffer in this case will function as an insulator where Rin the Voltage Controlled Oscilator/VCO circuit will not overload the multiplier circuit. If you don't use a buffer, the signal coming out of the multiplier circuit that enters the op-amp will be lost. This is because the resistance value R in the op-amp is so large. With a large R in value, Rin = ~, the circuit seems to be disconnected (short) so that the signal is still there, while with a small Rout value, Rout = 0, the signal will still pass. The Rin and Rout resistances are the same value, this is intended to produce a gain of 1x. The value of Rin = 10KΩ while Rout uses a variable resistor so that the value can actually be determined according to the resistance of Rin. A picture of the reversing buffer circuit is shown in figure 3. 3:

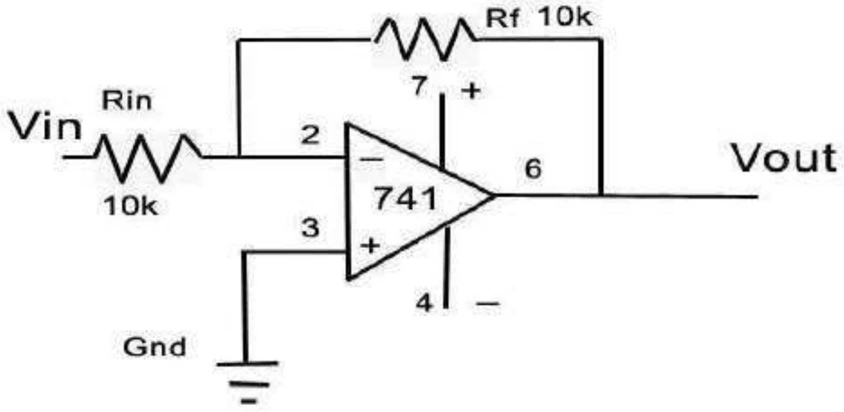

Figure 3. Reversing support strands (Source: M. Nurul Hudha)

Voltage Controlled Oscillator (VCO)

This voltage controlled oscillator (VCO) is capable of producing triangle and square waves. Like other VCOs, here the output frequency is determined by the size of the control voltage Vc. Voltage Controlled Oscillator (VCO) is an electronic oscillator whose output frequency is controlled by the input voltage (control). VCO is widely used in various electronic applications such as communications, signal processing, and control systems. where VCO works by converting the input voltage into a varying output frequency. The relationship between input voltage and output frequency is usually linear or can be defined by a certain function. The control voltage given to the VCO will determine how fast the oscillator oscillates, producing a frequency signal that varies according to changes in the input voltage. where VCO generally consists of several main components:

a. Voltage Comparator: Compares the input voltage with the reference voltage.
b. Frequency Generator Circuit: Produces a frequency signal based on the received voltage.
c. Voltage Adjuster: Adjusts the received voltage to suit the needs of the frequency generator circuit.
d. Linear VCO: Produces an output frequency that varies linearly with the input voltage.
e. Relaxation Oscillator VCO: Uses capacitors and resistors to produce oscillations based on the charging and discharging of the capacitor controlled by the input voltage.
f. Ring Oscillator VCO: Consists of several inverters connected in a ring whose frequency is controlled by the input voltage.
g. where PLL (Phase-Locked Loop) is applied: Using VCO to synchronize the frequency between two signals.
h. Frequency Modulation (FM): VCO is used to change the frequency of the carrier signal based on the information signal.
i. Frequency Synthesizer: Using VCO to produce the right frequency for various communication and signal processing applications.

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j. the advantages Frequency Flexibility: VCO can produce various frequencies based on the input voltage.
k. Accuracy and Stability: With the right design, VCO can produce frequencies with high accuracy and stability.
l. Easy Integration: Can be easily integrated into various electronic systems.

89C51 Microcontroller Minimum System

The minimum Atmel 89C51 microcontroller system must have certain specifications as follows:

1. It has an 89C51 microcontroller which has the task of processing power data which is read via counter input and displayed on the display.
2. Port 0 is used to display electrical power data processing using an 8 digit seven segment display
3. Port 1 is used for communication with a PC using Dual tone Multiple Frequency DTMF
4. Port 2 is used for the keypad system to enter data, interrupts and so on.
5. Port 3 is used to input electrical power measurement data from the VCO circuit using a timer/counter.

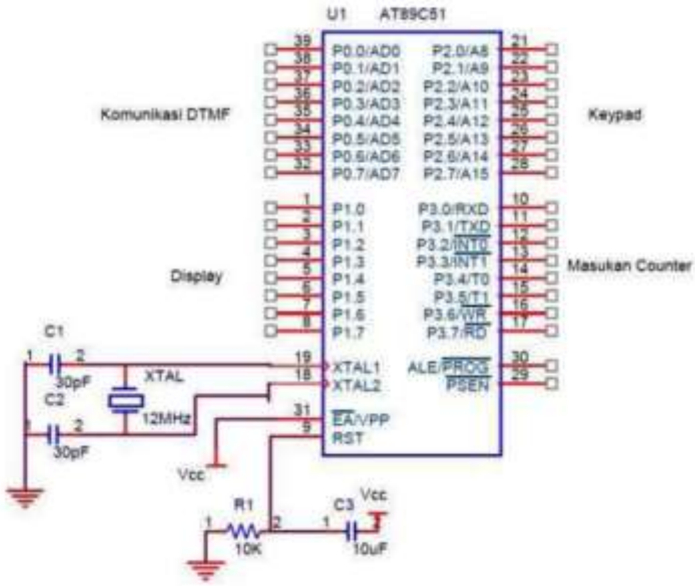

Figure 4. Minimum system for 89C51 microcontroller (Source: M. Nurul Hudha)

The input device with this counter/timer is a set of binary counters connected to the microcontroller data channel, so that the microcontroller can read the condition of the counter and if necessary the microcontroller can also change the condition of the counter.

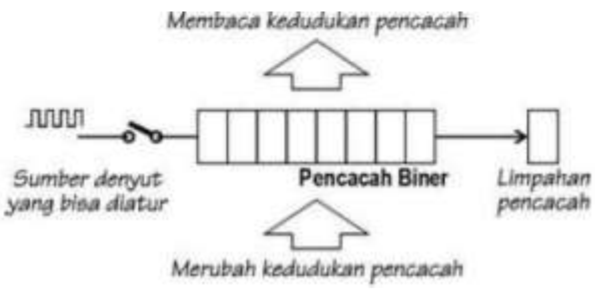

Figure 5. Basic concept of Timer/Counter as a means of input

A counter works as a timer, if a counter works with a fixed frequency whose magnitude is known, because the position of the counter is equivalent to a time that can be determined with certainty. The counter works as a counter, if a counter works with a frequency that is not fixed, the position of the counter only states the number of pulses the counter has received. Microcontroller family MCS51, for example the AT89C51 and AT89Cx051, is equipped with two Timer/Counter devices, respectively named Timer 0 and Timer 1. The Timer/Counter device is hardware that is part of the MCS51 microcontroller chip, for MCS51 microcontroller users the device is known as SFR (Special Function Register) which functions as internal data memory. Figure 3.5 is a complete diagram of the circuit arrangement that can occur in Timer 1, it also depicts the relationships of all the registers forming and controlling Timer 1.

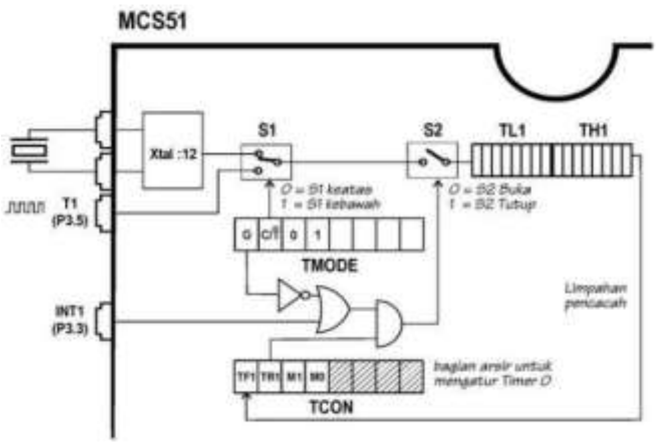

Figure 6. Complete schematic of Timer 1 in Mode 1

METHOD

This paper discussed an experimental approach, starting from collecting reference materials, selecting components, component layout, tool body design and LCD location, to creating a controller and monitoring application. To operate this tool, users must connect their smartphone to the tool via a Bluetooth connection. After that, users can enter a 20-digit electricity token number via the application on their smartphone. After receiving the data, Arduino will immediately forward it to the servo motor to press the kWh electricity meter keypad.

RESULT

Interrupt Vector Table

The prepaid electricity program consists of many programs that must all be served fairly. The service system for these program parts can be done in two ways, namely a looping system and an interrupt system. In a looping system each sub program will be called and served continuously and sequentially, while in an interrupt system sub-sub programs will be served when the sub-sub program interrupts the main program. In a looping system, the main program will actively provide services to each sub-sub program. This system has several weaknesses, apart from being time-inefficient, there is also no prioritization of the programs to be served. In an interrupt system, program parts will actively interrupt without having to wait their turn for service from the main program. Interrupt priorities are set in the Interrupt Vector Table program as shown in the following program fragment:

```
Org 0000h
Ljmp play
Org 0003h
Ljmp service_intr0

Org 000bh
Ljmp increment_counter_wave
Org 0013h
Reti
Org 001bh
Ljmp appears
Org 0023h
Reti
Org 002bh
reti
```

The highest priority for interrupts is the electrical power calculation counter program, then the DTMF communication service and the display system on the display. *Timers/counters*set to mode 1 with the command TMOD,#00000101B .

This means that:

On Timer 1 -- GATE = 0, C/-T = 0, M1 = 0, M2 = 0

On Timer 0 – GATE = 0, C/-T = 1, M1 = 0, M2 = 1

Bit C/T* ='0', according to Figure 4, this situation makes switch S1 to the top position, the pulse signal source comes from a crystal oscillator whose frequency has been divided by 12, the binary counter formed with TL1 and TH1 functions as a timer. To count pulses entering via leg 1 (P3.5), the position of switch S1 must be lowered by making the C/T* bit become '1'.

GATE bit='0', this makes the OR gate output always '1' regardless of the '0' or '1' state on the INT1 leg (P3.3). In this kind of situation, switch S2 is only controlled via bit TR1 in the TCON register. If TR1='1' switch S2 is closed so that the pulse signal from S1 is transmitted to the binary counter system, the pulse signal flow will be stopped if TR='0'. On the other hand, if the GATE bit='1', the OR gate output will follow the state of the INT1 leg, when INT1='0' whatever the TR1 bit state, the AND gate output always ='0' and switch S1 is always open, so that the S1 switch can be closed by the INT1 leg. and TR1 bits must be ='1' simultaneously. If the system being designed requires the work of the timer/counter to be controlled from a signal originating from outside the chip, then the GATE bit must be made to '1'.

Bits M1 and M0='0', meaning TL1 and TH1 are arranged into a 13 bit binary counter (Mode 0), if Timer 1 is desired to work in mode 1 as shown in Figure 4, then bit M1 must be made to '0' and bit M0 becomes '1'. The seven segment display program is a lower priority and because the 89C51 microcontroller only has one timer, the display program is superimposed/inserted on timer 1. This will have no effect because the human eye is not very sensitive to relatively short changes.

The data counter program snippet is as follows: mov

```
sp,#6fh
setb ip.1
mov tmod,#00000101b
setb ea
setb
et1
setb
et0
acall convers_wave mov
tl0,buffer_waveL mov
th0,buffer_waveH setb tr1
setb tr0
```

Data Fill Program

In this program the price of electric power per kwh can be determined easily. In the program to change the price per kwh or other things, there is no need to change many programs. Writing is simply done on the value to be replaced. This can be done because the decimal value has been represented by the program's hexadecimal value. The program pieces that can be changed by the operator are as follows:

```
Room number        equ   123h
Wave               equ   2
Price              equ   150h
Initial_voucher-s  equ   0500h
Voucher_initial_p  equ   0000h
```

Multiplier Circuit

The output signal from the voltage detector and current detector is fed to the multiplier circuit after previously being rectified by the diode component internal to the OTA 13600 IC. The brain as a multiplier of the OTA 13600 or 13700 amplifies the differential voltage applied at its input (pins 13 and 14) and outputs current, at the output (pin 12). The gain factor is expressed in mA/V and is referred to as transconductance (gm). The slope of this transconductance is relatively linear and changes as a function of the current (steering) flowing at pin 16. So the OTA amplifies the two variables and outputs the current as a product. Here one variable is the voltage tapped from the network and converted into steering current by P2 and R16. And the second variable is the voltage produced by the load current via R4.

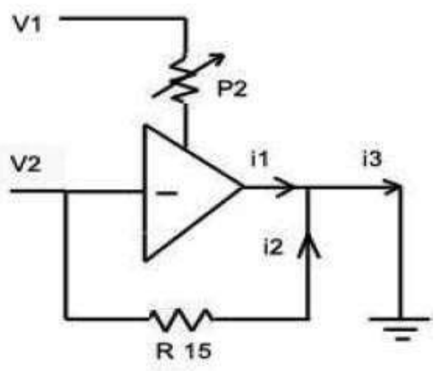

Figure 7. Equivalent circuit diagram of OTA as a multiplier.

In the figure OTA is depicted as an amplifier with a gm slope. The voltage translated from the load current is indicated by V2. The gm slope of the overturning OTA is set with P2. This circuit produces a current i3 that flows to chassis ground (or rather pseudo ground). The amount of i3 can be calculated as follows:

i3 = i1 + i2

i3 = - (gm +gm0) x V2 + V2
R15

gmo = slope at V1 = 0

gm = kx V1 (k = constant)

i3 = - (kx V1 + gm0) x V2 + V2
R15

i3 = -kx V1 xV2 – gm0 x V2 V2
R15

If P2 is set so that gm0 = 1
R15

13 =-kx V1 x V2 - V2 + V2
R15 R15

I3 =-kx V1 x V2

Meanwhile, the order of acceptance is as follows:

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1. When connecting P2, Vin 1 is given a voltage of zero volts or connected to ground. Vin 2 is given any constant voltage. Then P2 is set so that Vout is zero volts.
2. Connecting P1 is the opposite of the first step, namely Vin 2 is connected to ground and Vin 1 is given a constant voltage. Then P1 is adjusted so that Vout is also zero volts.
3. Trimming P1 and P2 is carried out several times to get optimal results.

The multiplier output voltage at pin 12 with various input voltage values can be seen in table 1:.

Table 1. Multiplier output measurement results for several input voltages

Vout (v)		Vin 1 (v)						
		-3	-2	-1	0	1	2	3
Vin2 (v)	-3	-0.71	-0.41	-0.16	0.03	0.3	0.5	0.7
	-2	-0.43	-0.26	-0.08	0.05	0.25	0.42	0.59
	-1	-0.20	-0.10	-0.05	0.04	0.15	0.24	0.32
	0	0	0	0	0	0	0	0
	1	0.24	0.13	0.07	-0.04	-0.15	-0.24	-0.32
	2	0.46	0.27	0.10	-0.01	-0.24	-0.41	-0.59
	3	0.69	0.41	0.15	-0.03	-0.36	-0.62	-0.87

Based on the table above, a four-quadrant multiplier characteristic transfer graph can be created using OTA 13600 in Figure 8 as follows:

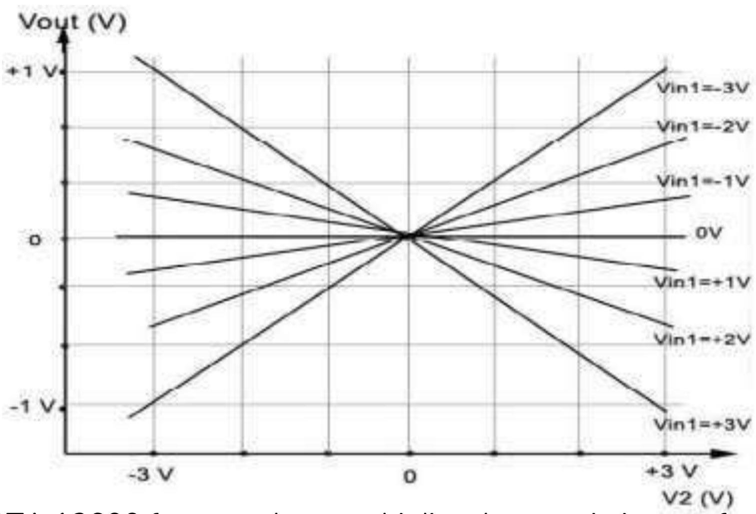

Figure 8. OTA 13600 four-quadrant multiplier characteristic transfer graph

Inverting Amplifier Circuit

The output of the multiplier circuit is an inverted (negative) voltage, so an inverting circuit is needed which also functions as a buffer. Buffers have the following characteristics:

Rin = ~

Rout = 0

$$-A = \frac{Rout}{Rin}$$

Because the reinforcement required is 1 time, the resistance values Rin and Rout must be the same:

$$-A = \frac{1}{1}$$

$$= -1 \text{ time}$$

For several load examples, the measurement results can be compared with the following calculations:

At a load of 10 W, it is known:

Vin = -24

Rin = 10K

Rf= 10K

$$Vout = -\frac{Rf \times Vin}{Rin}$$

$$= -\frac{10K \times -24v}{10K}$$

$$= 24 \text{ volts}$$

The circuit uses a resistor with a resistance value of 10 KΩ and a variable resistor whose resistance value can be changed. The use of a variable resistor was chosen because it makes it easier to determine the resistance value which is the same as the Rout resistance. The buffer in this case will function as an insulator where Rin the VCO circuit will not overload the multiplier circuit. If you don't use a buffer, the signal coming out of the multiplier circuit that enters the op-amp will be lost. This is because the resistance value R in the op-amp is so large. With a large R in value, Rin = ~, the circuit seems to be disconnected (short) so that the signal is still there, while with a small Rout value, Rout = 0, the signal will still pass. Based on the measurements, data on the relationship between the load size, voltage transformer output, current transformer output, multiplier circuit output and inverting buffer circuit output can be seen as shown in Table 2 below:

Table 2. Output measurement results of voltage transformers, current transformers, multipliers and inverting buffers

Burden (Watt)	Transformer output voltage (AC volts)	Transformer output current (AC volts)	Outputs Multiplier (millivolt dc)	Buffer output reverser (millivolt dc)
10	3	0.051	-24	24
20	3	0.105	-30	30
30	3	0.155	-36	36

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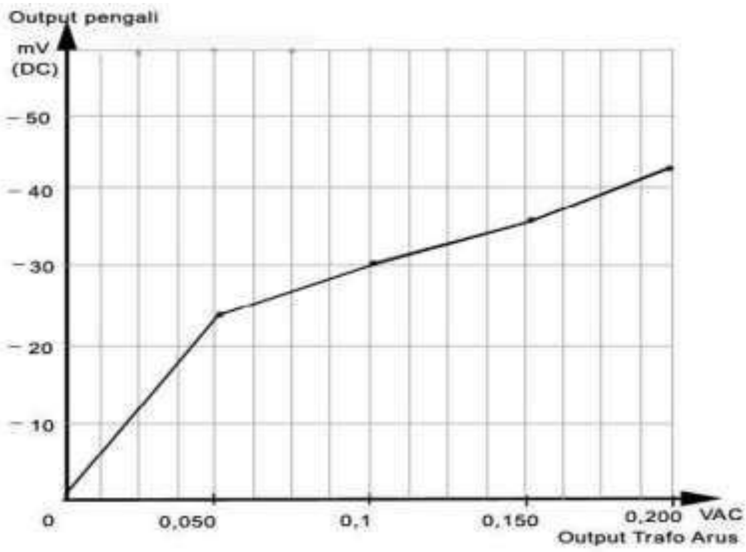

Figure 9. Graph of the characteristics of the relationship between changes in the current transformer output voltage and the multiplier output

The inverting output is in accordance with theory, so it can be fed to the Voltage Control Oscillator VCO circuit. From Table 2, a characteristic graph of the relationship between changes in the output voltage of the current transformer and the multiplier output can be made which is shown in figure 9.

Voltage Controlled Oscillator(VCO)

This voltage controlled oscillator (voltage controlled oscillator VCO) is capable of producing triangle and square waves. Like other VCOs, the output frequency is determined by the size of the control voltage Vc.. This oscillator is based on the integrator-comparator principle; here the condenser C1 is part of the integrator (circuit around A1). The condenser is charged by a constant current, and its level is determined by the instantaneous level of the control voltage, Vc and as a result the output of the comparator (circuit around A2) changes state and the TL transistor begins to conduct, when a low switching threshold is reached. The condenser C1 in this state dumps its charge and causes the output of A1 to increase (again, this voltage increases linearly). This process is repeated when the A1 output reaches the upper switching threshold of the comparator and the TL is turned off. The active factor of the output signal will be 50% if the value of R2 is the same as R3 and if the value of R1 is twice as large as R4 (R2 = R3 and R1 = 2 x R4). The relationship between R9 and R10 will determine the DC level of the triangle signal output. The circuit will produce a square wave output frequency F_2. Which inversely proportional to the control voltage $Vreff_2$.So the greater the price of $Vreff_2$then F_2getting smaller. The output of this string is F_2will be fed to the control thread as *base time*. Because the control circuit will produce a measurement time period that is inverse to the time base frequency, the greater the value of $Vreff_2$it will take longer the time the measurements are taken and the greater the measurement results. The frequency of the voltage controlled oscillator in the figure above can be determined using the equation

Fo = 2.5 Vs – Vreff)

RC vs

This voltage is the frequency control voltage that will be integrated by the integrator. When the integrator output voltage drops little by little to less than 8/3 V, the comparator input gets a high input and compares it so that transistor T1 is saturated. As soon as transistor Q becomes saturated, so the input voltage integrator becomes negative.

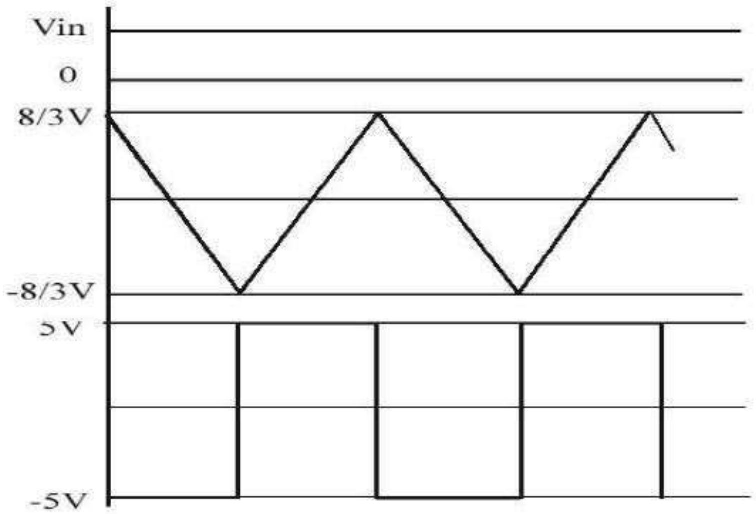

Figure 10. VCO waveform.

If the integrator output is slightly greater than 8/3 V, the comparator input will compare again and then disconnect the Q transistor.$_1$and voltage the integrator output drops to – 8/3 V again. This continues to repeat with a frequency proportional to the input voltage. The output ratio between input voltage and output frequency can be calculated as follows: $T_1$is the negative pulse width $Q_2$is the positive pulse width With R1=R2, it can be calculated:

When T1 the integrator output drops from +8/3V to – 8/3V

- 8/3 = 8/3 – Vin T1/ (4RC)

- 3/16 = - Vin T1 /(4RC)

T1 =64RC

3Vin

Meanwhile, at T2, the integrator voltage rises from –8/3V to +8/3V, the integrator is in a saturated state (on) so the integrator input voltage is Vth

Vth= Vin/3 – Vin/2

Vth= - Vin/6

Rth = 2R//R

= 2R/3

T2 can be calculated as follows;

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8/3 = -8/3 (-Vin T2/6)/(2RC/3) sec
3/16 = Vin T2 / 4RC
T2 = 64 RC/ 3Vin
T1 = T2
Period: T1 + T2
= 128 RC/ 3Vin
F = 3 Vin / (128RC)
F = 0.0234375 Vin / RC

From one of the circuits, for several examples of installed loads, a comparison of the measurement results between various installed loads, input voltage and output frequency produced by the VCO can be made as follows:

Table 3. installed load acomparison of the measurement result

Installed Load	VCO input voltage	VCO output frequency
(Watt)	(mvolts)	(Hz)
10	27	1.9
20	31	4.0
40	42	8.3
50	48	10.0
60	53	12.6

From this table, a graph can be made of the relationship between the VCO input voltage and the VCO output frequency in Figure 11:

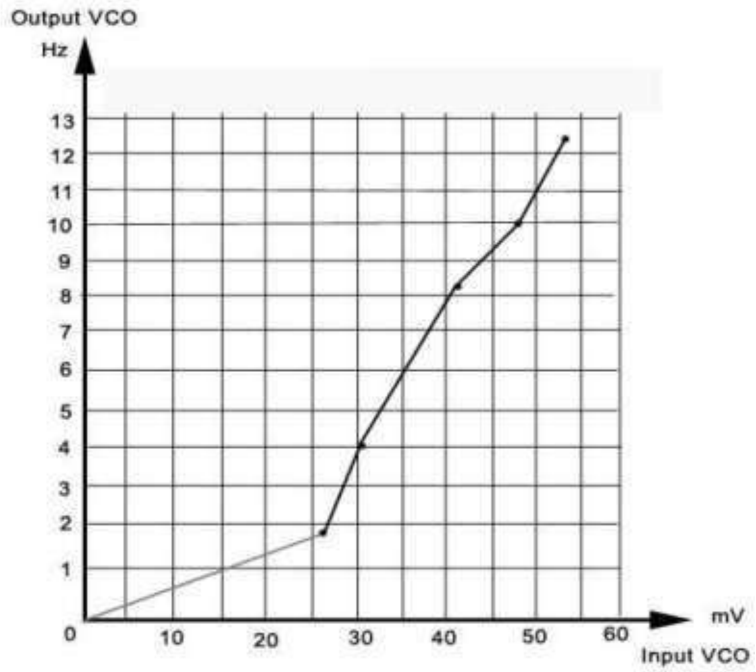

Figure 11. Graph of the relationship between input voltage and output frequency Voltage Controlled Oscillator/VCO (Source: M. Nurul Hudha)

Pricing per Kwh can be set easily, because the value entered in the program is a decimal number value which is presented as a hexadecimal number. For example, the price per kwh is 34. The data entered is actually hexadecimal data, but can represent decimal number data. This can be explained as follows:

3 4 h = 0 0 1 1 0 1 0 0

To get 4, the number 34h is multiplied by 01h = 0000 1111 binary = 04 decimal. To get 3, 34h is swapped and multiplied by 01h.This applies to room numbers, waves and vouchers.

CONCLUSION

The conclusion of this study is: This system allows users to easily top up electricity anytime and anywhere without the need for special equipment other than a telephone and Users can top up credit quickly via DTMF signals sent via the telephone network, increasing efficiency of time and effort. By using DTMF technology, this system reduces the risk of charging errors and fraud because the signals sent are directly and encrypted and This system ensures that only users who have access to the telephone with the registered number can top up credit, thereby increasing transaction security. The implementation of a DTMF-based prepaid system can reduce operational costs associated with the management and maintenance of a postpaid system By automating the credit top-up process, electricity companies can reduce administrative and labor costs. This system allows users to better monitor and control their electricity usage, thus helping them in household financial management and Users can purchase credit according to their needs and budget, thus avoiding energy waste. Overall, the design of a DTMF-based prepaid electricity credit top-up system offers an innovative solution that not only increases efficiency and convenience for users, but also provides higher economic and security benefits. This system is expected to be a step forward in more effective and efficient energy management and distribution.

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