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# Design and construction of a four-hourly digital alarm clock

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## ABSTRACT

*In this paper, we present the design and construction of a four-hourly digital alarm clock meant for regulating activities of persons in government parastatals, companies, higher institutions and industries. It was constructed using eight 7490 decade counters, eight 7447 decoders, eight seven-segment displays, two 555-timers and two comparators. Results of experimental tests have shown that it has an operating frequency of 1Hz, an alarm interval of 4 hours, alarm duration of 59.4 minutes and works in synchronization with any conventional time-piece. The last three of its characteristics have been found to be greatly resistance dependent and are optimized at a resistance, $R_v$ of 4.8KΩ*

**Key Words:** Design, Digital, Four-hourly, Alarm, Clock.

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## INTRODUCTION

Advances in digital technology have been phenomenal over the years, giving birth to digital systems which continue to serve as a great source of succour and comfort to mankind in many ways. These days, numerous applications in Electronics and other technologies use digital techniques to perform operations that were once performed by analogue methods. The digital systems owe their versatility and superiority over analogue methods to the fact that they are less affected by spurious fluctuations in voltage; have greater precision and accuracy; and can store billions of bits of information in a relatively small space [7]. These systems are mostly electronic, but can also be mechanical, magnetic or pneumatic.

The digital circuitry encompasses very fine and intricate connections made on integrated circuit (IC) chips found in operational amplifiers, 555-timers, 7490 decade counters etc. These devices are combined together in many applications to form digital circuits which operate on logical information or physical quantities which take on only discrete values. The digital circuits have applications in information storage, information transfer, automation, photography, instrumentation in laboratories, arithmetic operations and timing devices. Some familiar digital systems are digital computers, digital calculators, digital telephone systems and digital clocks.

A clock is fundamentally used for measuring time, but it may also be used to control a device designed to work according to time such as an alarm clock and a time bomb. Clocks may be analogue or digital. The analogue clock uses a fixed numbered dial and moving hands to indicate time. It also has a scale of 60 minutes as well as 60 seconds. A digital clock is " an electronic device" which " generates a repetitive series of pulses, known as clock pulses, whose frequency is accurately controlled" [1]. Digital clocks use electronic methods such as the 60 Hertz oscillator of ac power or a crystal oscillator. The digital clock typically displays a numerical hour range of 0-23, or 1-12 (am or pm) using liquid crystal displays or LED displays.
Digital clocks are very small, useful and inexpensive; therefore, they are often incorporated into bed-side alarm clock, radio, television, microwave ovens, watches, computers and cell phones. The purpose of this paper is to present the design and construction of a digital clock fitted with an alarm circuit which operates on a frequency of 1Hz and produces an alarm at a regular interval of four hours. The four-hourly digital alarm clock finds applications in highly sophisticated outfits to forecast weather, automate experiments ranging from nuclear reactions to biological culture processes in the laboratory. More importantly, it is meant to take care of human forgetfulness, creating public awareness about designed periods for various activities. In doing this, it helps to notify all persons in establishments such as companies, schools, government parastatals of to resume work, or have a break, or end the day's activities. To make optimal use of it, it is to be mounted or installed at a strategic position where the alarm produced is audible enough to be heard by everyone.

## 2.0 THEORETICAL LAYOUT

In this digital representation, quantities are represented by symbols called digits which may be any of the numbers from 0 to 9. The most common number systems used in digital technology are the decimal, octal, hexadecimal and binary systems. The octal number system is the base-8 system which consists of eight possible digits:0,1,2,3,4,5,6,7. Each digit of an octal number can have any value from 0 to 7. The octal number system is often used in digital computer work. The hexadecimal number system, called the base-16 system, is composed of 0 through 9 plus letters A, B, C, D, E and F as its 16 digits. Here the digits A through F correspond to the decimal values 10 through 15 [6] . One very interesting feature of all the number systems is that they are one to another.

The decimal system, also called the base-10 system has evolved naturally as a result of the fact that people have ten fingers. In fact, the word "digit" is derived from the Latin word "finger". This number system, used by people every day is the most familiar and consists of 10 numerals which are 0,1,2,3,4,5,6,7,8 and 9. Using these symbols as digits of a number, quantities of any form can be expressed.

In the binary system, the only two symbols or digits are 0 and 1. This is, therefore, called the base-2 system and can be used to represent any quantity that can be represented in the other number systems. However, it takes a greater number of binary digits to express a given quantity. For example, the number 4 in the decimal, octal and hexadecimal system has 100, 100 and 0100 as its binary equivalents. Like other number systems, this is a positional value system in which each binary digit has its value or weight expressed as a power of 2. In the floating point representation, the bits to the left of the binary point represent the integer part and the bits to the right represent the fractional part. Accordingly, the most significant bit (MSB) is the left-most bit (largest weight) whereas the least significant bit (LSB) is the right-most bit (smallest weight) [8].

Digital circuits are designed to produce output voltages that fall within the prescribed 0 to 1 range. The manner in which a digital circuit responds to an input is known as the circuit's logic. Each digital circuit obeys a set of logic rules and as such is called logic circuit. Examples of logic circuits are gates and multiplexers.

Digital signals are representations of discrete data often derived from analogue data. An analogue signal is a datum that changes continuously over time [3] . Temperature at a given location and the amplitude of a voltage at a certain node in a circuit are examples of analogue signals, which can be represented as mathematical functions having time as the free variable and the signals themselves as dependent variables. A discrete signal is a sampled version of an analogue noted at fixed intervals (every microsecond) rather than continuously. If individual time values of the discrete signal are approximated to a certain precision, the resultant data stream is called a digital signal. The process of approximating the precise value within a fixed number of digits, or bits, is called quantization.

In most applications, digital signals are represented as binary numbers, so the precision of quantization is measured in bits. The main advantage of digital signals over analogue signals is that they are immune to the imperfections of the electronic systems which tend to spoil analogue signals.

The building blocks of the digital clock are shown in figure 1; and the functional relationship between them is schematically represented.

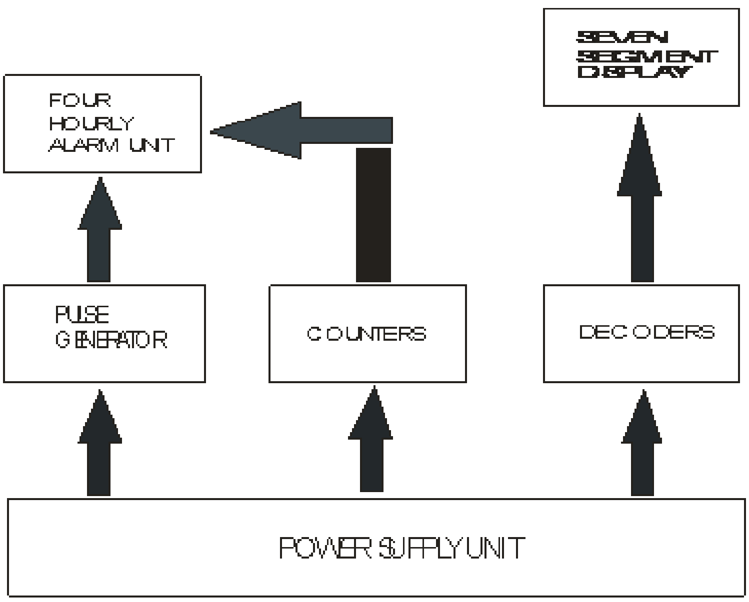


**Figure 1: Schematic Diagram of the Four-Hourly Digital Alarm Clock**

The power supply unit is built to power the entire system for effective operation. It embodies a transformer, a rectifier, a filtering capacitor and a voltage regulator. The transformer steps down ac voltage, the rectifier provides a full-wave rectified dc voltage, the filtering capacitor removes ripples from the dc voltage and the regulator a constant output voltage. Voltage regulation is achieved by using a 7805 integrated circuit (IC) regulator.

The pulse generator helps to produce the appropriate frequency required to drive alarm clock signal. The effective operation of the digital clock depends on it greatly. A 555-timer, configured as an astable multivibrator is used as the pulse generator.
The counters are employed to enhance frequency division in the clock system. They are the 7490 asynchronous IC counters which operate such that one counts from 0 to 9 and the other from 0 to 5. The 0-5 counter is called the divide-by-6 (DB6) counter whereas the 0-9 counter is called the divide-by-10 (DB10) counter [8] .

The 7447 decoders are meant to detect the presence of a specified combination of bits at their input and produce a corresponding output level. The binary coded decimal at their input provides an output to drive a seven-segment display. It is basically a combinational logic circuit which converts an n-bit binary input code into a maximum of $2^n$ unique output lines [2]. Its major components are logic gates.

The seven-segment display displays an already decoded signal from the decoder. A light emitting diode (LED) display emits light energy as current which passes through the individual segments.

The four-hourly alarm unit serves to produce an audible alarm using a 555-timer as an oscillator. It produces sound at an interval of four hours.

## DESIGN CONSIDERATIONS

The selection of optimal digital circuit components for the implementation of the alarm clock was one of the most important considerations made in this work. To ensure fidelity of operation, the following circuit components, based on different integrated circuit technologies, were considered.

The choice of the transformer was based on the voltage (V) and current (I) specifications: $V = 12V$, $I = 1.5A$
The area of the transformer core is: $a = 1.152(IV)^{1/2}$ ------------- (1) [5]

It is a step-down transformer having the turn ratio:

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} \qquad (2)$$

where $V_p$, the primary voltage is 240V while $V_s$, the secondary voltage is 12V and the turn ratio is 20. $V_{peak} = \sqrt{2}V_{rms}$ , - - - - - - - - - (3)

where $V_{rms} = 12V$. Hence, $V_{peak} = 16.97V = V_m$.

And $V_{dc} = 2V_m/\pi$ - - - - (4)

Therefore, $I_{dc} = V_{dc}/R = 1.5A$ - - - - - (5)

R is the load resistance in the power supply.

The ripple factor, $\square = V_{\square}/V_d$ - - - - (6)

where $V_{\square} = 4.97$, $\square = 0.65$

The filtering capacitance, $C = I_{dc}/4\sqrt{3}fV_{\square}$ - - - - (7)

where f, the frequency of the power source is 50Hz. Thus, C = 871μF.

To ensure a more thorough filtering, a greater capacitance of 3300μF was chosen.

For voltage regulation, a choice was made of a 7805 IC voltage regulator to take an input of 12V and produce a regulated output of 5V.

In the pulse generator, the 555-timer used generates a continuous stream of on-off pulses which switches between two voltage levels. The period (T) and frequency (f) of the pulses are expressed as: $T = 1/f$ - (8)

where f depends on $R_A = 1K\Omega$, $R_B = 60K\Omega$ and $C = 0.01\mu F$.

$T = t_1 + t_2$ - - - - - (9)

where $t_1 = 0.693R_BC$ - - - - (10)

and $t_2 = 0.693(R_A + R_B)C$ - - - - (11)

From equation 6, T = 838.53μs.

Using equation 5, f = 1.2KHz, meaning that the pulse generator operates at this frequency.

The 7490 decade counters chosen are the DB10 and DB6 types which are used in seconds and minutes sections to count from 0 – 59. Here the DB10 counter counts from 0 – 9 while the DB6 counter counts from 0 – 5. Their connection in the hour section is such that the DB10 counts from 0 – 3 and the DB6 counts from 0 – 2 after which both of them recycle. In the four-hourly section, the DB10 counter counts from 0 – 3 and recycles whenever 3 equals 4 while the DB6 counter remains at 0.

The 7447 decoder used in the alarm clock is meant to take a 4-bit binary coded decimal (BCD) input and provide an output that passes current through the appropriate seven-segment display. The resistance of each limiting resistor connected to a LED in the seven segment display is:

$R_s = (V_{cc} - V_{rated}/I_{rated})$ - - - - (12) [4].

where $V_{rated}$ = minimum voltage to turn on the LED =2.5V, $V_{cc}$ = 5V and $I_{rated}$ = $10^{-3}$A is minimum current to turn LED on.

From equation (12), Rs = 250Ω. Since there are seven LEDs, each with its own limiting resistance, $R_s$ =$R_1$ = $R_2$ = - - - - - =$R_7$ = 250Ω.
The four-hourly alarm circuit is designed to produce an audible sound with the aid of a 555-timer connected in the monostable mode. The period of pulse produced is:

$$T = RC/2 \qquad - \qquad - \qquad - \qquad - \qquad (13)$$

where R = 300M Ω and C = 24Mf, T =3600s, which implies that the alarm duration is 1 hour.

## CIRCUIT DESCRIPTION

The circuit is shown in figure 2. It comprises a 5V supply, eight 7490 counters, eight 7447 decoders, eight seven segment displays, a pulse generator, two comparators, a buzzer and two 7408 AND gates. The output of the power supply is connected to the pulse generator which is connected to the input (pin 14) of the first counter (DB10); all the counters are cascaded. The counters are, in turn, connected to the input (pins d, e, f and g) of the decoders which are connected the seven segment digital displays. Finally, the comparators are connected between the output of the counters in the four-hourly section and the input of the alarm unit. The output of the alarm is the buzzer which connected to the collector of the transistor, Q.

All the circuit components were first connected on a breadboard (test board), and were transferred to a permanent circuit board when found to function as designed.

When a regulated voltage of 5V is supplied to the circuit, a pulse is generated by pulse generator and fed into the input, pin 14 of the cascaded 7490 decade counters. In the second’s section the DB10 counter counts from 0 – 9 and the DB6 counter from 0 – 5. The one pulse per second signal fed into the second’s section is utilized by these counters to count from 0 through 59 seconds by blinking one count per second. After 59 counts, the DB10 in the minutes section will count from 0 – 9 and recycles to 0 after 9 minutes, triggering the DB6 counter and causing the DB6 to advance one count. This continues from 1 through 5 during which the DB6 is at 0101(5) and the DB10 counter is at 1001(9), so that the digital display reads 59 minutes. The next pulse recycles the counters (both recycle every 60 minutes). The output of the DB6 counter in the minute’s section has a frequency of pulse per hour. The pulse is fed into the hour section which causes the DB10 counter in the four-hourly alarm section to advance one count. This continues in such a way that, when the hourly section counts, in hour, from 0 through 3, the four-hourly section counts, in hour, from 0 through 3. This implies that the hourly section count is at 0 – 2 whereas the count in the four-hourly section is at 0 – 3. Consequent upon this, the comparators connected to the four-hourly alarm section compare digits 3 and 4 from left and reset when 3 equals 4, thus giving the much desired output for the alarm circuit.

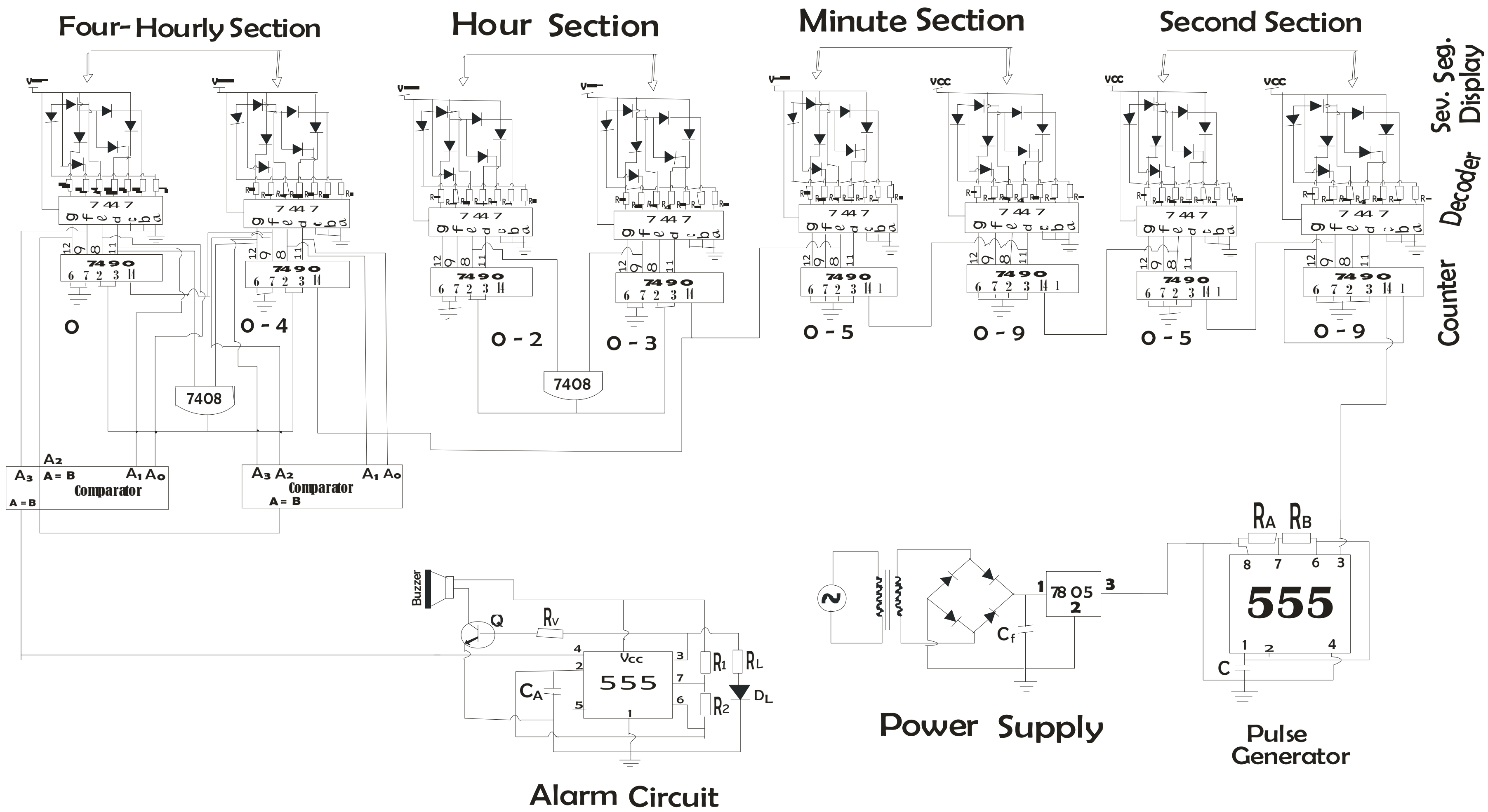


Figure 2: The Four-Hourly Digital Alarm Clock

## TESTS AND RESULTS

### *TESTS*

Following implementation, various tests involving voltage regulation, accuracy (synchronization), alarm duration, alarm interval were conducted.

To determine the regulating action of the voltage regulator, the circuit's power supply was connected to the mains under a no-load condition and the output voltage was measured using a voltmeter. The power supply was then connected to the circuit (load) and the voltage across its output terminals was measured. The readings taken indicated that the no-load voltage was higher than the voltage measured under the full-load conditions. The results are in table 1

The alarm duration test was meant to verify how long the alarm sounded. For this purpose, the digital alarm was monitored (watched closely) and timed just the moment it began sounding the alarm using a stop-watch. Observation showed the alarm lasted for about one hour.

The accuracy test was carried out to synchronize the alarm clock with a conventional time-piece. Doing this, both the clock and the stop-watch were first set at zero, and then the variable resistor, $R_v$ of the alarm clock was adjusted to its minimum value (4KΩ). After some time, readings were taken and recorded. This test was repeated three more times. Secondly, $R_v$ was adjusted to its maximum value (7KΩ) and the readings of the stop-watch and the alarm clock were noted and recorded. Thirdly, $R_v$ was varied continuously to find the specific resistance at which the digital clock works in synchronization with a conventional time-piece, and it was observed that at 4.8KΩ, both of them indicated the same time. The results are presented in table 1.3.

The alarm interval test was aimed at determining how long it took the alarm to sound at 7KΩ, 4KΩ and 4.8KΩ. The readings taken are shown in table 1.2.

## RESULTS

| No-load Voltage (V) | Full-load Voltage (V) |
|---|---|
| 5.5 | 4.5 |

**Table 1.1: Output Voltages Under No-Load and Full-Load Conditions**

| | $R_v$ = 4.0KΩ | $R_v$ = 4.8KΩ | $R_v$ = 7.0KΩ |
|---|---|---|---|
| Alarm Duration, $t_d$ (min) | 52.3 | 59.4 | 26.0 |
| Alarm Interval, $t_i$ (hrs) | 3 hrs, 6.4 min | 4 hrs | 1 hr, 18.2 min |

**Table 1.2: Alarm Duration and Alarm Interval**

| | $R_v$ = 4.0KΩ | $R_v$ = 4.8KΩ | $R_v$ = 7.0KΩ |
|---|---|---|---|
| Stop-watch Reading, $t_w$ (min) | 29.0 | 30.0 | 30.0 |
| Alarm Clock Reading, $t_a$ (min) | 29.0 | 30.0 | 69.0 |

**Table 1.3: Result of Synchronization Test**

## DISCUSSION

In the course of experimentation, the output voltage under no-load conditions was found to be higher than the one measured under loaded conditions. This agrees perfectly with the laws of electricity. The voltage source had to do some work to overcome the internal resistance of the entire circuit, thereby dissipating some electrical energy which is represented by a voltage difference of 0.6V in table 1.1. This is also demonstrative of the regulating action of the voltage regulator considering the fact that it was designed to produce an output of 5V under loaded conditions.

The synchronization test carried out between the digital alarm clock and the conventional time-piece has shown that they were perfectly in agreement at a resistance of 4.8KΩ. This clearly demonstrates the suitability of the alarm clock for the desired purpose. If kept in a public place, it would keep correct time, giving good guidance to people as to the schedule of daily activities. As shown in table 1.3, the digital alarm clock and the conventional time-piece are out of synchronization at $R_v$ equals 7.0KΩ. This implies that synchronization is resistance-dependent and is best achieved at 4.8KΩ.

The alarm interval was verified and to be exactly 4 hours at a resistance of 4.8KΩ. The results of table 1.2 confirm this. This is another convincing proof of the appropriateness of the alarm clock for the purpose of its design and construction.

The alarm duration is shown in table 1.2 to be 59.4 minutes, instead of 1 hour, at a resistance of 4.8KΩ. This difference of 0.6s is not worrisome thing at all. The alarm duration can be easily reduced or increased at will by making a little modification to the alarm unit of the digital clock.

Finally, the role of the variable resistor, $R_v$ in the alarm clock is quite interesting, informative and indispensable. It has been seen to control alarm duration, alarm interval and synchronization. These are three very important factors that determine the accuracy and suitability of the alarm clock.

## CONCLUSION

The design and implementation of the four-hourly digital alarm clock have proven to be very successful. It is durable and cost-effective. It is strongly recommended to government parastatals, all levels of academic institutions, companies and industries as an accurate and adequate means of regulating daily activities of employees, staff and students.

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