Lab 10

Digital Meets Analog

REFERENCE: Horowitz and Hill Sections 8.20 [one-shot]
Section 5.14 [555 timer]
Section 9.15-9.16, 9-20 [DAC& ADC]

INTRODUCTION

" In this lab we will test IC's used to interface digital and electronic circuits. The first is a popular chip for making oscillators, the `555. Next is the monostable multivibrator (One-Shot) which can produce a jitter-free trigger signal from a rising or falling analog input. Finally we will set up an digital-to-analog converter (DAC) and an analog-to-digital converter (ADC).

EQUIPMENT

Analog Oscilloscope	
Function generator	
Pulse generator	
DC power supply	
Prototyping board	
Capacitors	0.1 μF (3), 0.01 μF, 0.001 μF
Resistor	3k (2), 5.1k (2), 10k (2)

Integrated circuits:

74121	one shot
LM555 or 7555	timer
DAC0808	8-Bit Digital-to-Analog Converter
ADC0804	8-Bit Analog-to-Digital Converter

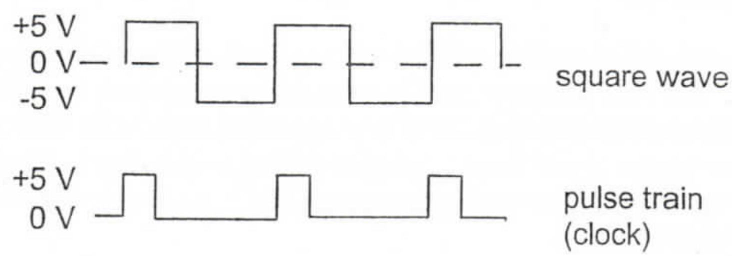
Edited by John Goree 2 January 2004

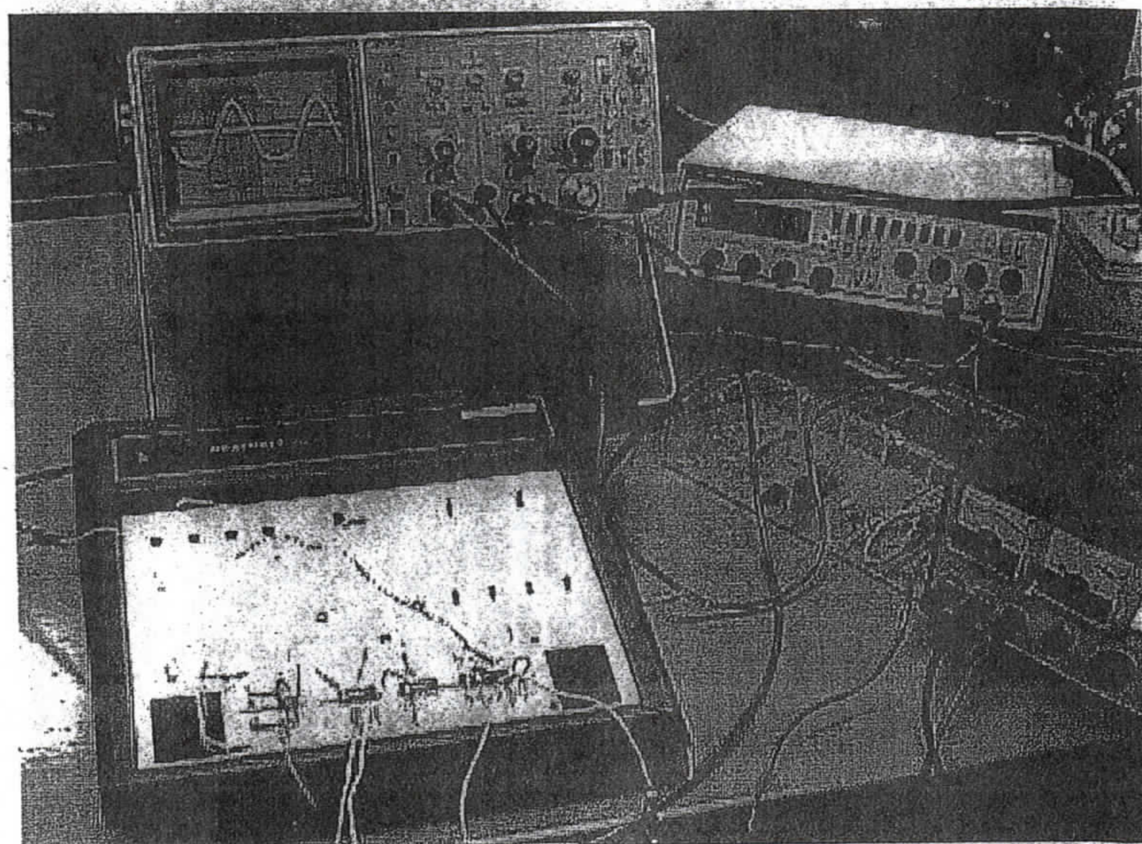
❝ The terms "pulse generator" and "square wave generator" refer to different things.

A "square wave generator" is usually a bipolar oscillator. The waveform swings from positive to negative voltages. Sometimes it has a feature to add an arbitrary DC offset to the output.

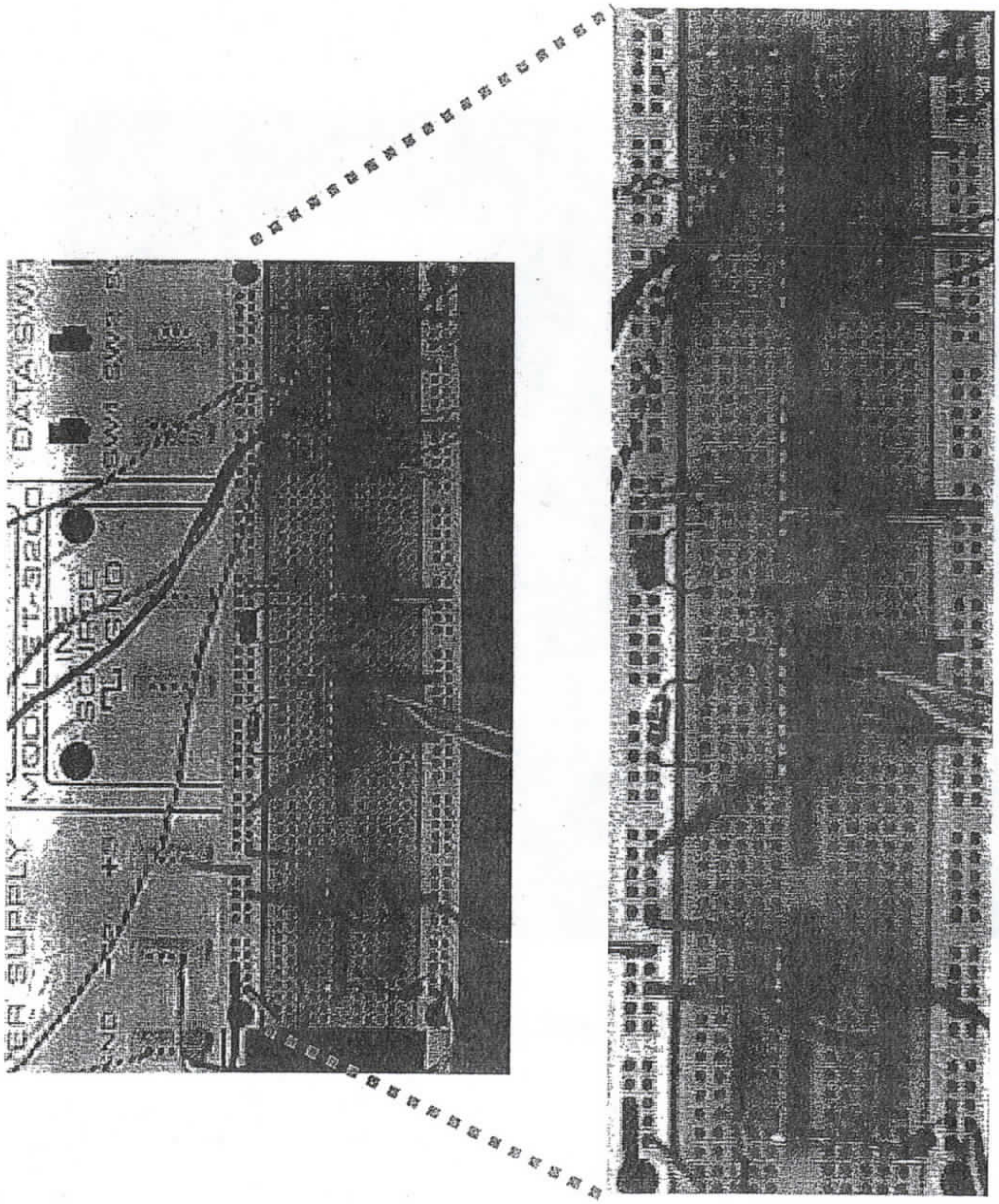
A "pulse generator" is usually not bipolar, and there is usually no DC offset adjustment. A pulse swings between zero and either a positive voltage (as in the case of logic circuits) or a negative voltage.

Pulse generators are used to clock digital circuits.





Lab 10 setup



Lab 10 circuit, as wired on the prototyping board at the end of the Lab.

PROCEDURE

1. 555 Timer, used as an oscillator

66 Timer circuits are common in many of the instruments that are "home-built" in research laboratories. A favorite and easy-to-use chip is the 555 timer, or a modernized version such as the 7555. With this chip, you can easily build a simple oscillator or other waveform generator.

66 Here you will build a square wave oscillator.

☛ Using the prototyping board, build the circuit shown in the figure. Use +5 V from your prototyping board for V_{CC}. (V_{CC} = +15 V should work too.)

(a) ☛ Use the oscilloscope to observe the waveforms at the output and at pin TH.

☛ ✍ Measure the duty cycle of the output waveform.

Duty cycle ≡ fraction of time the output voltage is "high"

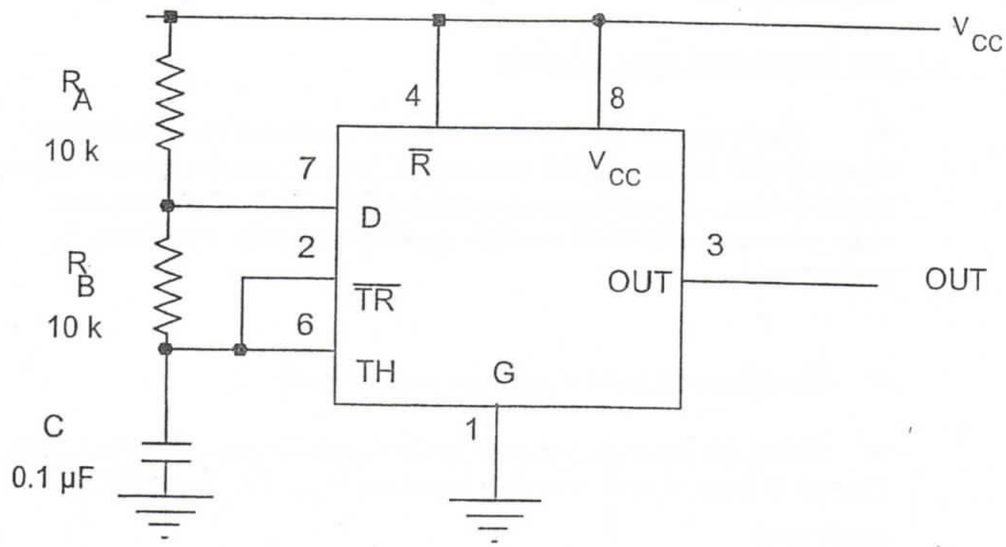
Specify your answer in percent, e.g. 37.5 % ± 5%.

(b) ☛ ✍ Measure the frequency. Compare it to the predicted value:

$f_{osc} = 1 / [\, 0.7\, (R_A + 2\, R_B)\, C\,]$.

(c) ☛ ✍ Replace R_B with a short circuit.
Observe the resulting waveform.
Explain your observation.

☛ Leave this circuit hooked up. You will use it with the one-shot in the next part.

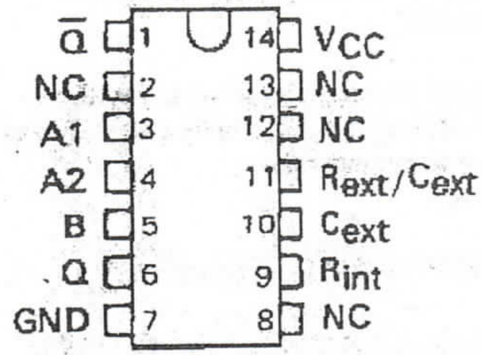


555 Timer square-wave oscillator

2. Monostable Multivibrator One Shot (74LS121)

" The output of a one-shot is a digital pulse triggered by an analog waveform at its input. Even if the input is noisy, the one-shot will produce a clean pulse. The pulse has a width determined by an *RC* time, and the pulse height is determined by the input voltage.

SN74121 . . . N PACKAGE
(TOP VIEW)



FUNCTION TABLE

INPUTS			OUTPUTS	
A1	A2	B	Q	$\overline{Q}$
L	X	H	L	H
X	L	H	L†	H†
X	X	L	L†	H†
H	H	X	L†	H†
H	↓	H	⊓	⊔
↓	H	H	⊓	⊔
↓	↓	H	⊓	⊔
L	X	↑	⊓	⊔
X	L	↑	⊓	⊔

“ The One-Shot you will use has a <u>Schmitt-trigger input</u> (for the B input). Schmitt trigger inputs fire when the input exceeds a certain threshold, and reset when the input voltage drops below a lower threshold. Schmitt triggers are widely used to produce a jitter-free pulse from a noisy input signal.

☛ Referring to the specification sheet, connect the '121 on the prototyping board as follows. Connect an 0.1 μF capacitor between pins 10 and 11. The one-shot you will use has an internal timing resistor with a nominal value of $R_{int} = 2$ kΩ (refer to the data sheet to confirm this value).

1.	$\overline{Q}$ output	8.	NC
2.	NC	9.	Timing pin: Short to pin 14
3.	input A1 = GND	10.	Timing pin: C+
4.	input A2 = GND	11.	Timing pin: C-
5.	input B	12.	NC
6.	Q output	13.	NC
7.	GND	14.	+5 V

(a) ☛ Set up the function generator to apply a 10V P-P sine wave with $f \approx$ 1 kHz.

☛ ✍ Vary the input amplitude and see what happens. What is the trigger voltage?

☛ ✍ Measure the pulse width. Compare to $R_{int}\, C \ln 2$.

(b) ☛ ✍ Repat with a pulse generator instead of a function generator, making the pulse. Reduce the pulse width and verify that the pulse width at the output of the one-shot is unaffected by the pulsewidth at its input.

(c) ☛ ✍ Replace the shorting wire between pins 9 and 14 with a 10 k resistor, and measure the pulse width.

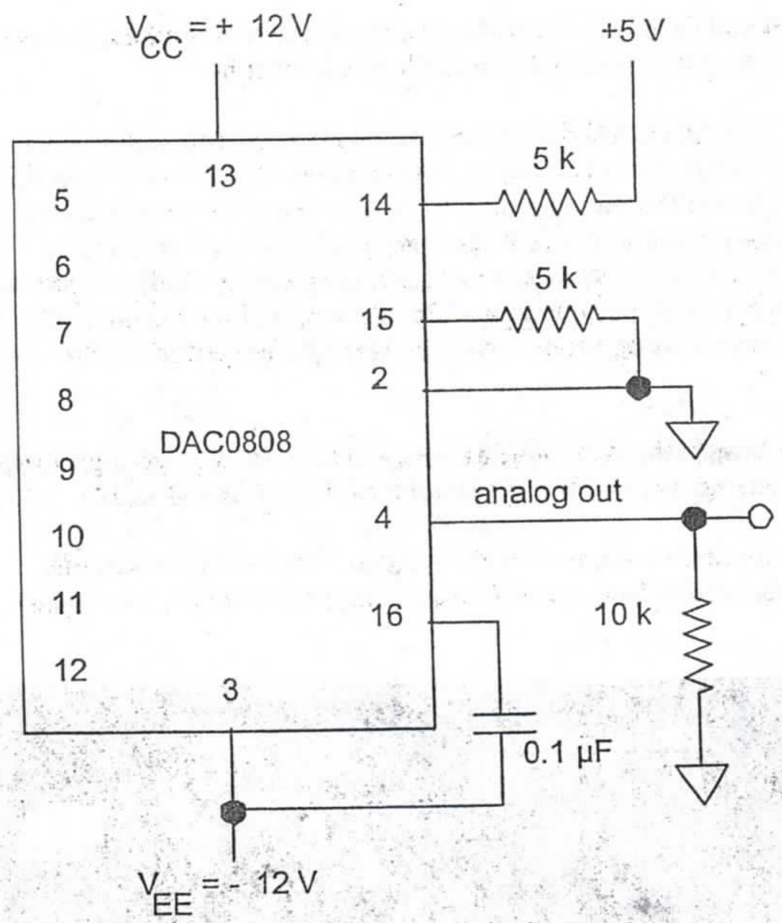
(d) ☛ ✍ At the input, replace the signal from pulse generator with the square wave signal from the 555 timer that you built in part 1. Verify that this combination works as a pulse generator.

3. Digital to Analog Conversion (DAC0808LCN or equivalent)

“ The DAC0808 is an easy-to-use 8-bit D to A converter (DAC).

☛ Wire up the DAC as shown in the figure. Use wires to connect the inputs of the three most-significant bits (MSBs) on pins 5, 6, and 7 to the input switches on your prototyping board. Connect the other four inputs to LO by connecting pins 8 through 12 with wires directly to ground. Connect a multimeter to the analog output, pin 4.

☛ ✍ Make a table showing all eight possible combinations of the digital input states on the three most-significant bits. Then measure the analog output V_{out} for all of these states.



4. Analog-to-Digital Converter

[Note: This circuit requires ≈ 23 wires to hook it up on your prototyping board.]

“ An ADC is often used to interface digital circuits or computers to the real world, especially to acquire data. Your digital multimeter, for example, has an ADC. Among other things, an ADC contains comparators and voltage reference levels. The incoming analog signal is compared to the voltage reference levels to determine which is closest. A corresponding digital output bit is then set to TRUE.

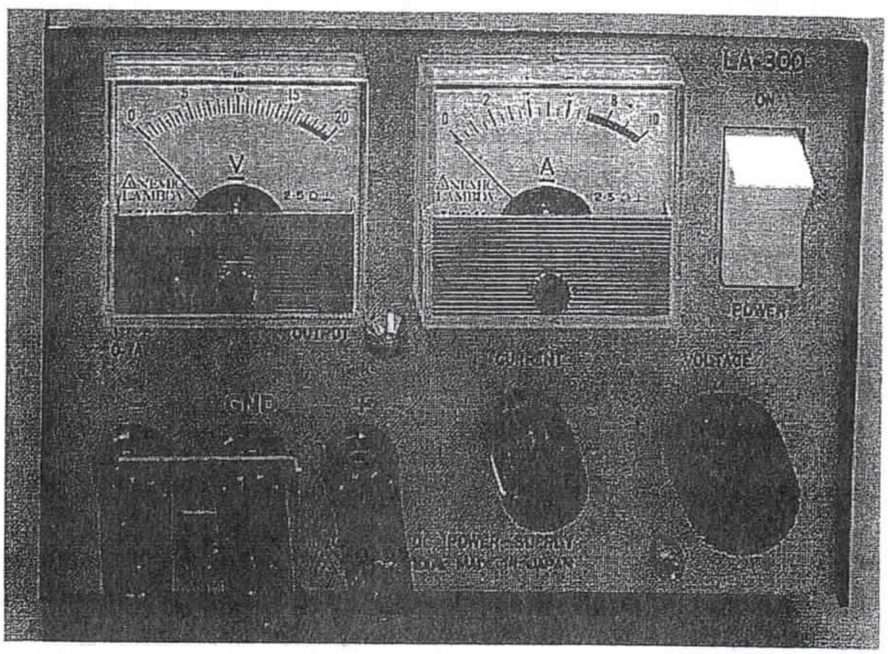
“ An ADC is rated by the number of bits and the maximum clock speed.

“ Here we will use the ADC 0804, an inexpensive ADC that is contained on one chip. It digitizes eight bits at a clock speed up to 1.4 MHz. It can be clocked by an external pulse source, or by connecting a resistor and capacitor to make a simple relaxation oscillator (analogous to the way the 555 works); we will do the latter here.

“ The ADC 0804 has two analog inputs for differential voltage measurement. For convenience in testing this ADC, we will ground one of the differential inputs (pin 7) and to the other one (pin 6) we shall apply a simple dc voltage. One way of doing this is to use a voltage divider as a voltage source, with an op-amp voltage follower to assure a low output impedance. The op-amp follower is not critical here if you use a voltage source with a low output impedance to drive it.

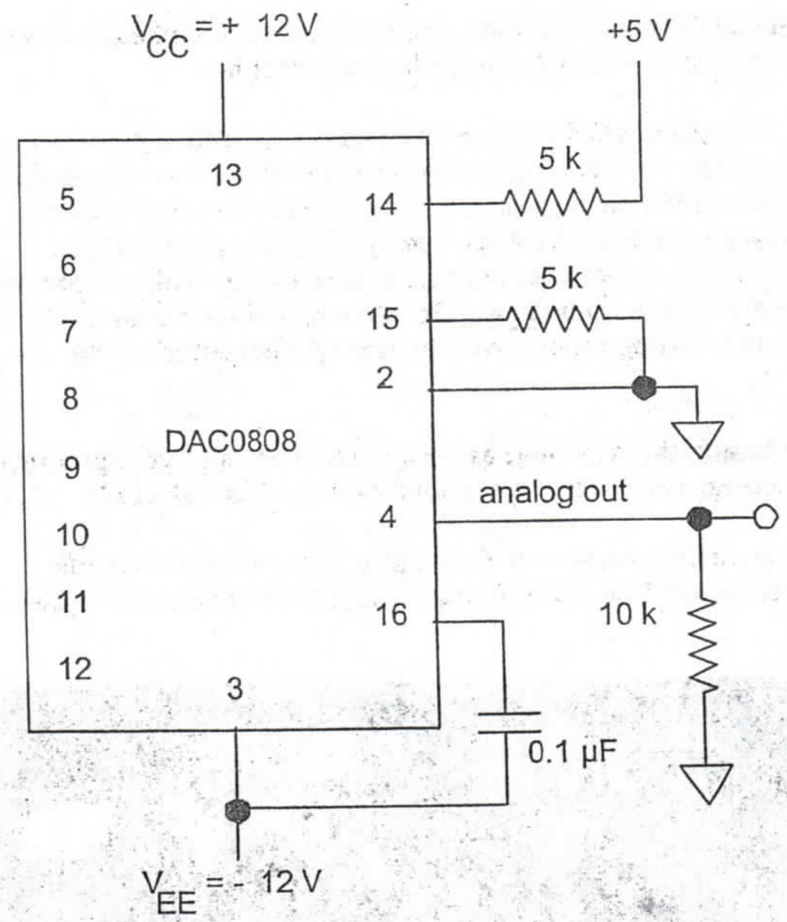
☞ Connect the ADC0804 as shown. Use LED's on your prototyping board to indicate the four most significant bits (pins 11 to 14).

☞ Pay careful attention to the grounds. The analog and digital grounds are different, and this circuit might not work if you connect



them.

☞ Use a bench power supply (see photo) as an adjustable voltage source. Be sure its negative terminal is connected to its ground, and connect that ground to your circuit's ground



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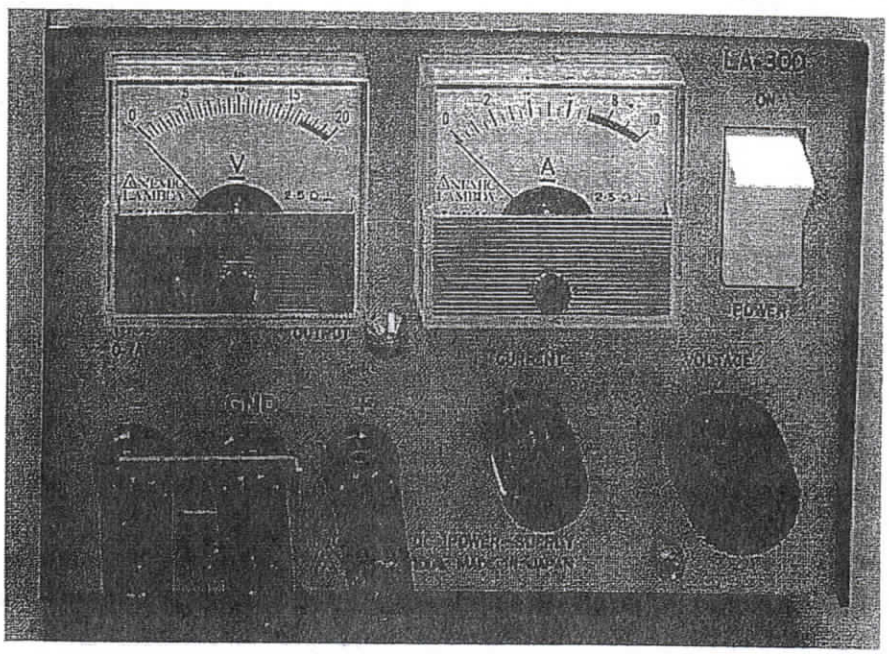

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(a) Clock

☛ ✍ Using an oscilloscope, look at the waveform on pin 19, and draw it. Confirm that there is a 5 V, 100 kHz clock signal present. [This frequency is determined by R and C, as it was in the 555 timer.]

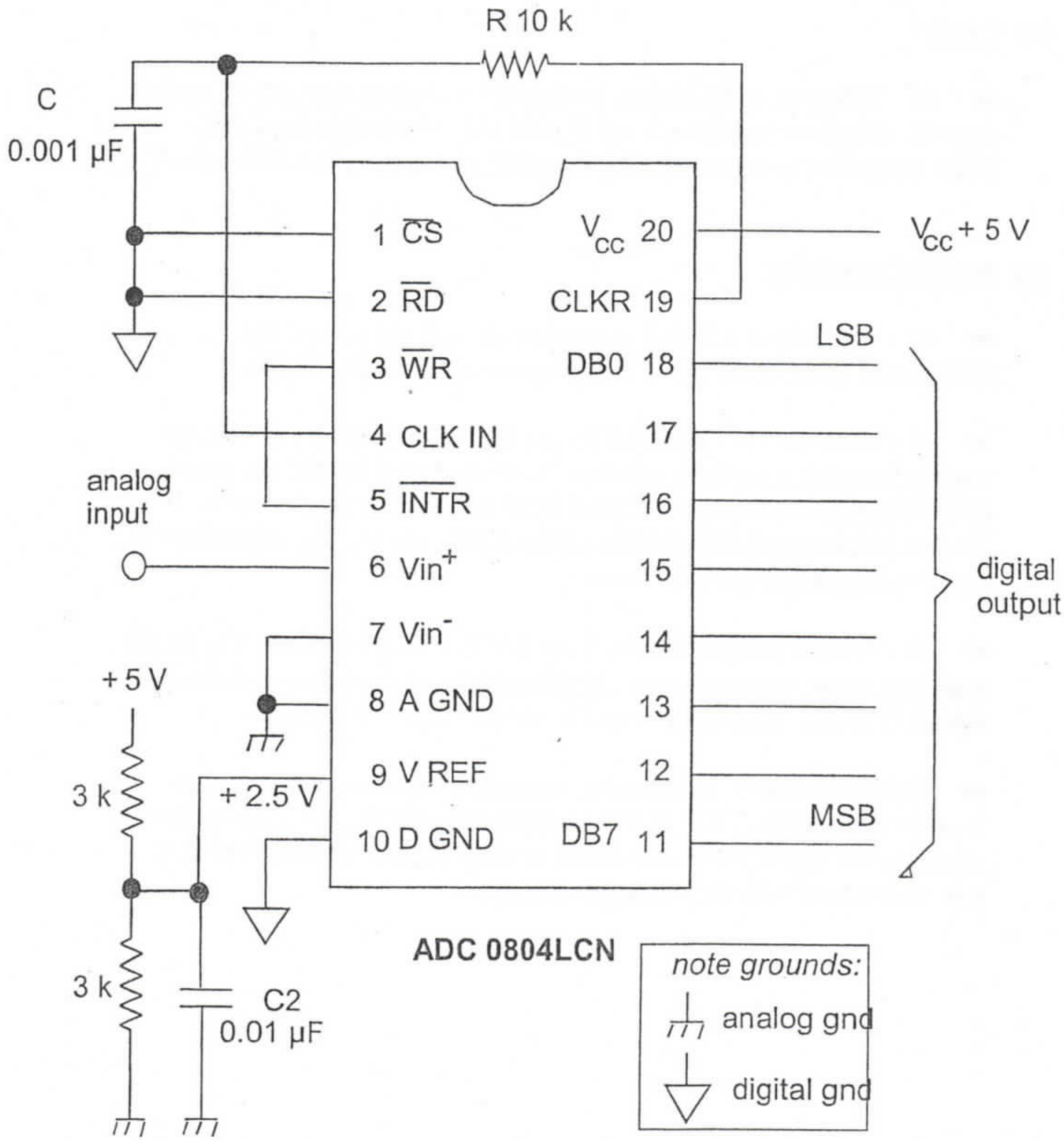
(b) A to D Conversion

☛ ✍ Connect a DMM to measure dc voltage across the differential input to the ADC (i.e., between pin 6 and ground).

☛ If it looks like too many LEDs are lighting up, the input voltage may be jittering near the borderline between digital levels, causing a fast alternation between one digital level and another, and because of the fast clock speed, it looks like all the LEDs are lit. Try adjusting the input voltage slightly up or down.

☛ ✍ Vary the input voltage from 0 V to 5 V, and record V_{in} (at the 8 levels) where the three most significant bits of digital output change from LO to HI. Present your results in the form of a table.

☛ Using the function generator, produce a triangle wave (or sine wave)e varying from 0 V to 5 V at approximately 0.1 Hz, and apply this signal to the input. Watch the LEDs as they change, and be sure that you understand why they change as they do.



Test circuit for the ADC 0804 analog-to-digital converter.

Use the GND on your prototyping board as both the analog and digital grounds.

The purpose of C2 is merely to reduce noise in the voltage divider's output; it is not a critical component.