FINAL REPORT MINI PROJECT

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CREATIVE ELECTRONICS

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Proposal

Our goal is to develop a system keeps the humidity of potting soil in which a plant is planted, constant. To achieve this, we need a system which consists of two parts:
The first part of the system monitors the humidity of the potting soil, and checks it against a set threshold. When the humidity dips below the threshold, the system activates part two.
Part two is the system that supplies water to the soil to water it.
We are going to try to develop this system without using Arduino or equivalent microprocessors, but solely use passive components and IC's to achieve our goal.

Components

The first thing we need, around which we can base our circuit design, is a sensor. The choice went to an analog soil moisture sensor by RobotDyn (http://www.tinytronics.nl/shop/Sensoren/Temperature-Air-Humidity/RobotDyn-Bodemvocht-Sensor-Module-). This sensor outputs a voltage that varies with the moisture of the soil.

To determine if the plant needs watering, this voltage should be compared against a reference. To compare this, we need a comparator. In this case we used an opamp as a comparator, more specifically the 'LM358N Dual Opamp'. The opamp outputs a voltage when the source attached to pin '+' has a higher voltage than that attached to pin '-'.

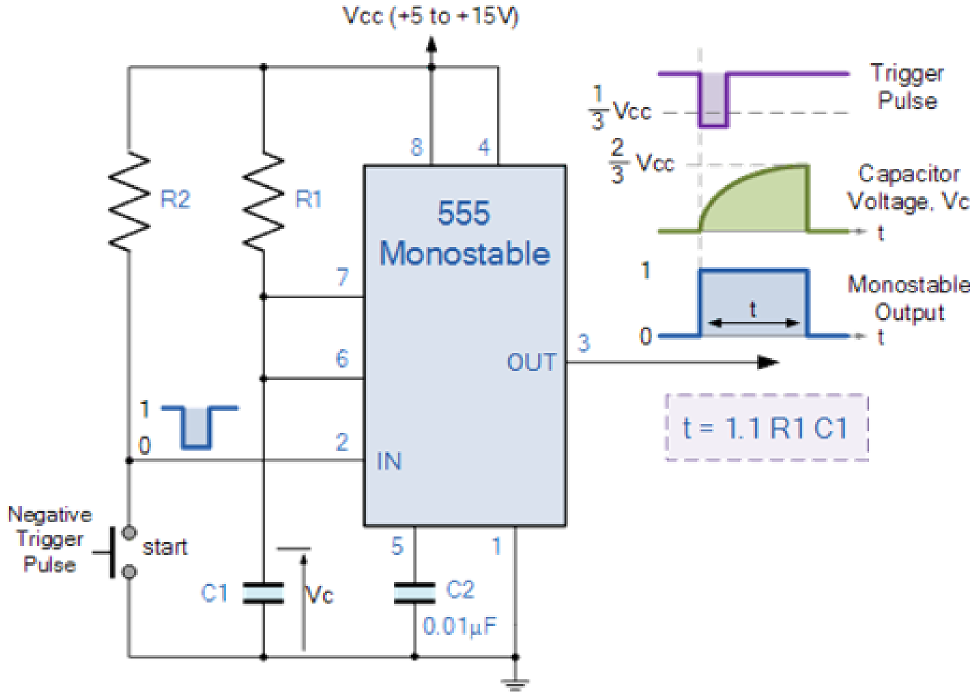
To know whether the sensor should be attached to '+' or '-', and what the reference voltage should be, we will take some measurements using dry and moist soil in a following section.

Next, we will need to make sure the plant gets enough water. To do this, the actuator should be turned on for a minimum amount of time when the soil is dry. This is because the sensor immediately changes value when the water starts pumping, but this doesn't mean that the plant has had enough water.

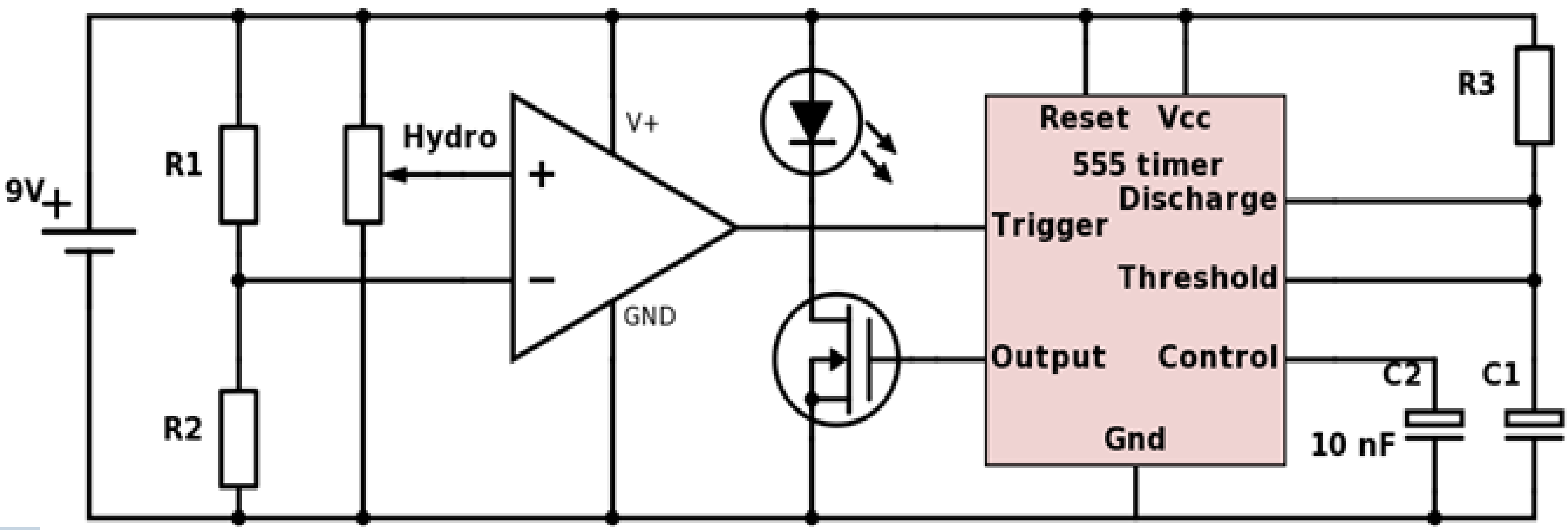
To make sure the pump is always on for at least 5 seconds, we will use a 555 timer in monostable mode. In monostable mode, the 555 timer produces a pulse of a set time when triggered externally.
For a waterpump, we selected a submersible pump that operated on a low voltage (not mains), this to prevent to need to use a relay for switching. The pump we ordered: https://www.bitsandparts.eu/Motoren-Servos-and-Drivers/Doseringspomp-Waterpomp-dompelpomp-3-6V-120l-h/p116339.
The advantage of this pump, is that the water doesn't come anywhere near the electronics. The pump is submerged in the water tank, and just needs power to operate and a tube to feed the water out.

Design

It would be great if our circuit could operate on a battery. We're going to look into the possibility of using a 9-volt battery to power the entire system. All of our components can handle 9 volts, except for the pump. We can use a voltage divider to power the pump in a later stadium, right now we will test using only a LED instead of the pump. Below is a proposal for the design of the circuit. We will need to calculate R1 and R2 based on the measurements of the soil, C1 and R3 need to be based on the minimum amount of time we want to trigger the actuator for.



The use of the 555 timer is based on the following circuit (http://www.electronics-tutorials.ws/waveforms/555_timer.html):



Circuit proposal

Measurements

Next, it is time to perform some measurements on the sensor to see how it responds to moisture. We used a pot of dry soil and wet soil to measure the difference in output voltage at 5V and 9V input.

	Dry	Wet
5V	3.42V	2.11V
9V	4.86V	3.01V

As we can see, the voltage drops when the soil is moist.

Calculations

Formula for voltage divider:

$$V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$$

When using a voltage of 5V, the reference should be around 3.3V (see measurements). When the sensed voltage rises above this, the plant should be watered.
When R1=10kΩ and R2=20kΩ, Vout= 3.333V. (See schematic above for R1 and R2).

When using a voltage of 9V, the reference should be around 4.7V.
When R1=10kΩ and R2=10kΩ, Vout=4.5V.

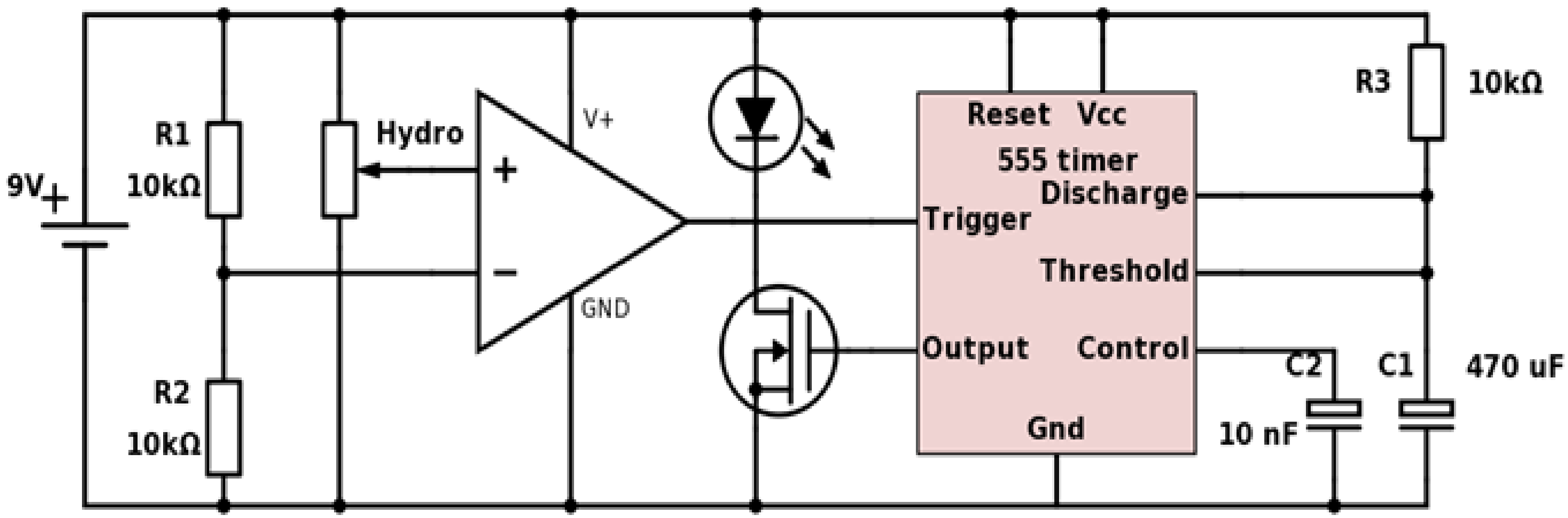
We want the plant to be watered for at least 5 seconds.
$T=1.1R3*C1$

We have a lot of 10kΩ resistors, so we will use that for R3.

$$C1 = \frac{T}{1.1R3} = \frac{5}{1.1*10000} = 4.55 * 10^{-4}F$$

This means C1 should have a value of around 455 uF. The closest we could find has a capacitance of 470 uF, resulting in a T of 5.17 seconds.

The voltage over the sensor gets higher when the soil becomes dry, so the opamp should turn on when the measured voltage is above the reference voltage. This means that the sensor should be connected to the '+' pin of the opamp, and the reference to the '-' pin.



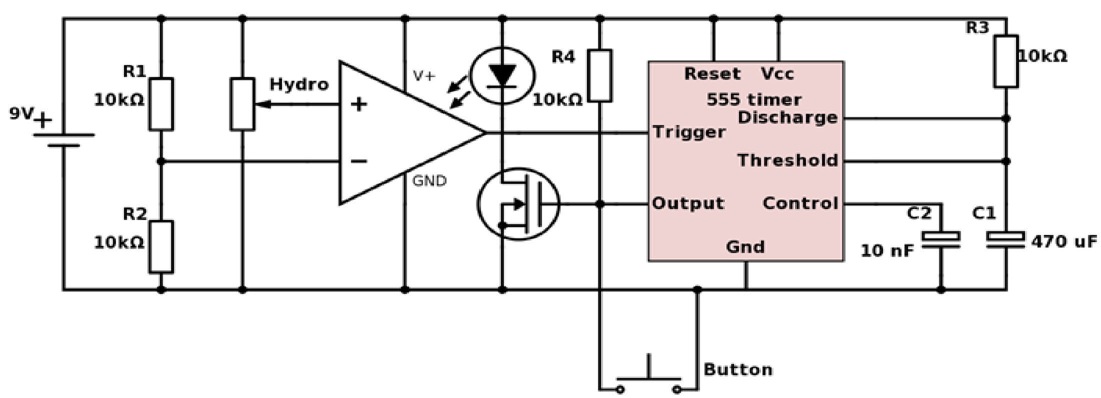
The new version of the circuit

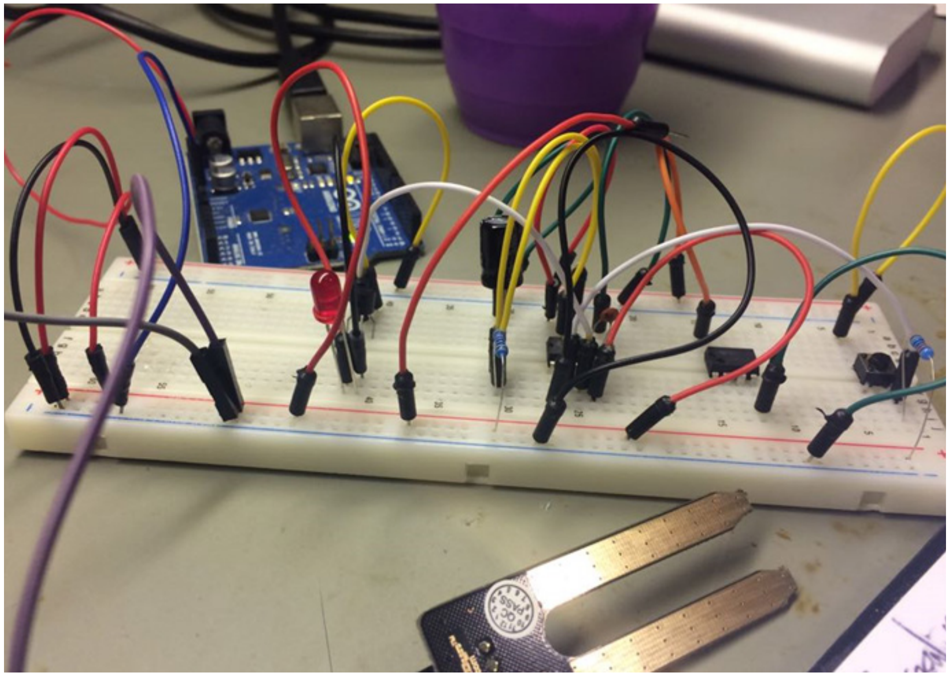
Realising the product

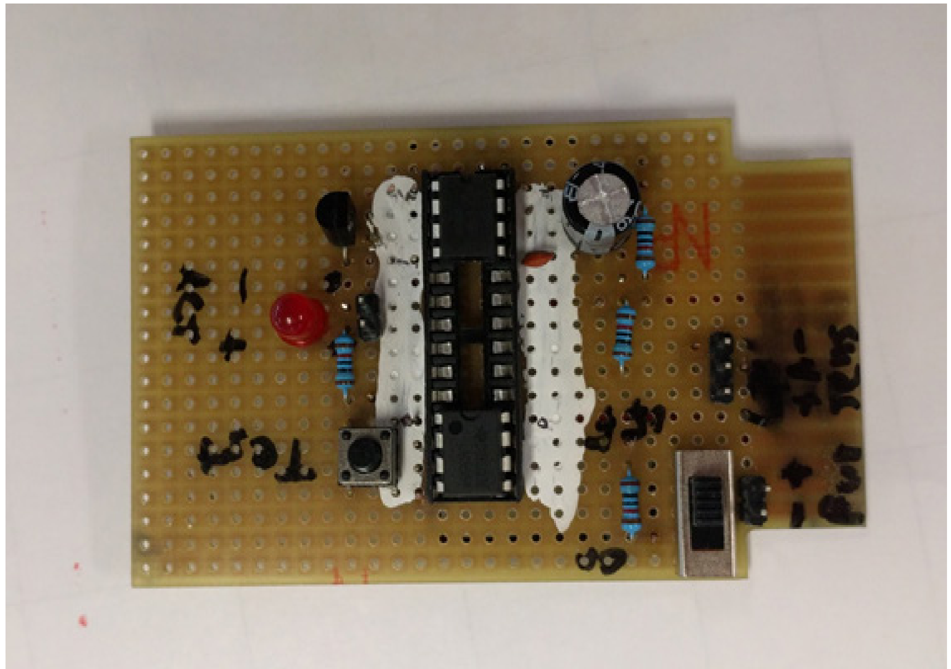
Now it is time to place all the components on a breadboard, and test the functionality. The final component list is as follows:

- Soil moisture sensor
- Opamp (LM358N)
- Timer 555 (NA555P)
- Transistor (NPN BC337-40)
- Capacitor C1 (470uF)
- Capacitor C2 (10 nF)
- Resistor R1 (10kΩ)
- Resistor R2 (10kΩ)
- Resistor R3 (10kΩ)
- Battery (9V)
- Water pump

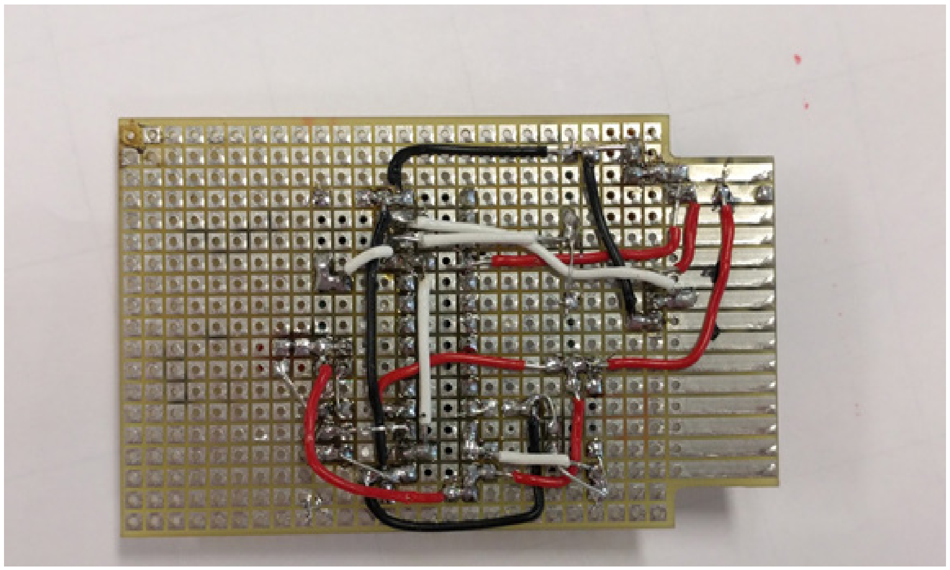
While assembling, we found out it would be useful to have a button to test the functionality of the water pump and the 555 timer. We added it in the following way:







When this all functioned correctly, we moved everything to a PCB for a more permanent solution.



We used headers to connect the battery, sensor and actuator to make sure it is easy to install, but we can still troubleshoot the PCB without permanently attached wires.

Future improvements

As you might have noticed, we have not been able to show our product functioning with the water pump installed. This is because of the simple fact that the shipping of our pump got delayed until beyond the deadline. We were unable to get a similar pump from another retailer. When the pump does arrive, it is a matter of attaching the positive and negative leads to the headers on the PCB.

We measured the current drawn by the circuit in idle state (water pump inactive) to be 53.6 mA. The 9V battery we are using has an electric charge of 550 mAh.
This means that our design will be able to run for 10.26 hours on idle. This isn't nearly enough to make into a feasible product, especially considering the fact this doesn't take the water pump into account. To make this a feasible product, we would need a way larger or rechargeable battery. Another option is to still connect it to mains power, but that would be a lot less practical since it would add the necessity of having a power socket near the plant.

We will also need to connect the sensor in a better and more beautiful way, while also redesigning our enclosure. Another addition we can make, is to add two potentiometers to the Plantie. One potentiometer adjusts the reference voltage, so reference can be adapted to different soils and plant preferences. The other one adjusts the timing of the 555 timer, to increase or decrease the signal time and thus change the amount of water given to the plant.

In conclusion, this product is a good and functioning prototype but there is still a lot of room for improvement, especially concerning power consumption and power sources.

Sources

Texas Instruments. (2017). LMx58-N Low-Power, Dual-Operational Amplifiers. Retrieved from http://www.ti.com/lit/ds/symlink/lm358-n.pdf

ON Semiconductor. (n.d.). BC337, BC337-25, BC337-40. Retrieved from https://www.onsemi.com/pub/Collateral/BC337-D.PDF

Texas Instruments. (2010). xx555 Precision Timers. Retrieved from http://www.ti.com/lit/ds/symlink/ne555.pdf

Electronic Tutorials. (2017, January 15). 555 Timer Tutorial - The Monostable Multivibrator. Retrieved from http://www.electronics-tutorials.ws/waveforms/555_timer.html
Circuits designed at: http://www.digikey.com/schemeit/project/

Appendices

Texas Instruments

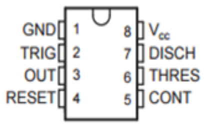
NA555, NE555, SA555, SE555

www.ti.com

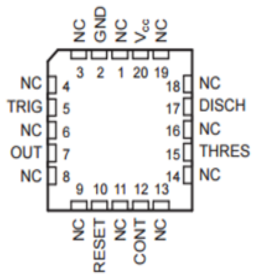
SLFS022I – SEPTEMBER 1973 – REVISED SEPTEMBER 2014

6 Pin Configuration and Functions

NA555...D OR P PACKAGE
NE555...D, P, PS, OR PW PACKAGE
SA555...D OR P PACKAGE
SE555...D, JG, OR P PACKAGE
(TOP VIEW)



SE555...FK PACKAGE
(TOP VIEW)



NC – No internal connection

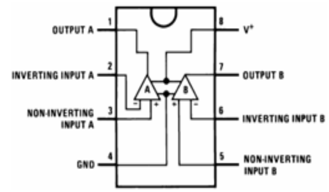
Pin Functions

PIN NAME	PIN NO. D, P, PS, PW, JG	PIN NO. FK	I/O	DESCRIPTION
CONT	5	12	I/O	Controls comparator thresholds, Outputs 2/3 VCC, allows bypass capacitor connection
DISCH	7	17	O	Open collector output to discharge timing capacitor
GND	1	2	–	Ground
NC		1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	–	No internal connection
OUT	3	7	O	High current timer output signal
RESET	4	10	I	Active low reset input forces output and discharge low.
THRES	6	15	I	End of timing input. THRES > CONT sets output low and discharge low
TRIG	2	5	I	Start of timing input. TRIG < ½ CONT sets output high and discharge open
V_{CC}	8	20	–	Input supply voltage, 4.5 V to 16 V. (SE555 maximum is 18 V)

NA555P

5 Pin Configuration and Functions

D, P, and NAB Package
8-Pin SOIC, PDIP, and CDIP
Top View



6.1 Absolute Maximum Ratings

See (1)(2)(3).

			LM158, LM258, LM358, LM158A, LM258A, LM358A MIN	LM158, LM258, LM358, LM158A, LM258A, LM358A MAX	LM2904 MIN	LM2904 MAX	UNIT
Supply Voltage, V^+				32		26	V
Differential Input Voltage				32		26	V
Input Voltage			−0.3	32	−0.3	26	V
Power Dissipation (4)	PDIP (P)			830		830	mW
	TO-99 (LMC)			550			mW
	SOIC (D)			530		530	mW
	DSBGA (YPB)			435			mW
Output Short-Circuit to GND (One Amplifier) (5)	$V^+ \le 15$ V and $T_A = 25°C$			Continuous		Continuous	
Input Current ($V_{IN} < -0.3V$) (6)				50		50	mA
Temperature			−55	125			°C
	PDIP Package (P): Soldering (10 seconds)			260		260	°C
	SOIC Package (D)	Vapor Phase (60 seconds)		215		215	°C
		Infrared (15 seconds)		220		220	°C
Lead Temperature	PDIP (P): (Soldering, 10 seconds)			260		260	°C
	TO-99 (LMC): (Soldering, 10 seconds)			300		300	°C
Storage temperature, T_{stg}			−65	150	−65	150	°C

LM358-N

BC337, BC337-25, BC337-40

Amplifier Transistors

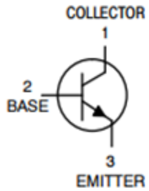
NPN Silicon

ON Semiconductor®

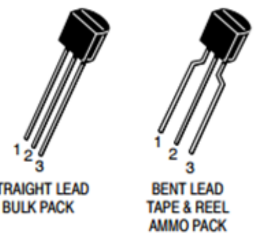
http://onsemi.com

Features

- These are Pb−Free Devices



TO−92
CASE 29
STYLE 17



MARKING DIAGRAM

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector – Emitter Voltage	V_{CEO}	45	Vdc
Collector – Base Voltage	V_{CBO}	50	Vdc
Emitter – Base Voltage	V_{EBO}	5.0	Vdc
Collector Current – Continuous	I_C	800	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12	W mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction−to−Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction−to−Case	$R_{\theta JC}$	83.3	°C/W

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be

NPN BC337-40