Plant Watering

Technical Documentation

# Introduction

This document explains (mostly) all of the relevant considerations I had while designing this project. Since I am not an electronic engineer, I cannot guarantee any correctness of the following calculations, designs, explanations, etc. Therefore, this document shall not be seen as an exhaustive step-by-step manual of how to design such a device. But merely a diary of the author to don’t lose track during the development which – frankly – took way too long in the first place.

# Project Scope and Main Requirements

The goal is to develop a device which can irrigate multiple containers for plants. It should do so by considering not only the measured value of the soil moisture, but also today’s weather forecast. Meanwhile it should keep the user constantly updated via a Telegram chat bot or MQTT (or both).

Therefore, the device needs to be capable of the following features:

* Multiple inputs for analogue soil moisture sensors
  + The number of sensors was relatively arbitrarily set to 8
* Multiple outputs for electromagnetic valves to distribute the water
  + The number of valves must match the number of sensors
  + Since I received a free set of 10 very beefy valves which are usually used in trucks, those valves pretty much dictate most of the power requirements of the circuitry.
    - 24 V
    - 5 A peak to open the valve
    - 1 A to hold the valve open
* One output for a pump
* Small OLED display to show important information without the need of a mobile phone
* Download and interpret weather forecast
* Send updates and information wirelessly
  + MQTT
  + Telegram
  + (App)
* User configurable wirelessly
  + MQTT
  + Telegram
  + (App)

# Power Supply

## Resettable Fuse

### Selecting IC

In this section, the main selection criteria for a suitable buck converter shall be explained. Following the criteria, one specific example is given.

Most importantly, the main power requirements have to be met. Coming from the chosen electromagnetic valves, those requirements are the following:

|  |  |
| --- | --- |
| nominal operating voltage | V = 24 V |
| nominal operating current | I = 1 A |
| peak current | Ipeak = 5 A |

Additionally, there are some secondary requirements, ordered by priority:

* Compact package due to space constraints
* Pricing
* Good availability

According to those requirements, the onsemi NIS4461MT3TXG[[1]](#footnote-1) seems to be a reasonable choice.

### Dimensioning of RLIM

According to NIS4461MT3TXG datasheet and onsemi document AND9441/D[[2]](#footnote-2), RLIM is directly connected to the current limiting pin (pin 4, ILIM). According to fig. 12 of the datasheet setting RLIM to 20 Ω should lead to following behaviour:

Overload current IOL of around 4,6 A and then limiting the current to ISC of around 2,1 A.

For more precise current limiting behaviour, a precise resistor with relatively low temperature coefficient and relatively high accuracy should be used.

### Slew Rate dv/dt

According to NIS4461MT3TXG datasheet.

Note: Use ceramic capacitor!

The standard current ramp-up according to the datasheet is 2 ms. For a softer startup, an external capacitor of Cext = 470 pF was added. That increases ramp-up time by a factor of 10 to 20 ms.

### Source Pins

For smoothing and decoupling purposes, a ceramic capacitor of 100 nF was added to each source pin of the fuse.

## Step Down (Buck) Converter

### Selecting IC

In this section, the main selection criteria for a suitable buck converter shall be explained. Following the criteria, one specific example is given.

Main selection criteria, ordered by priority:

* Variable in- and output voltage
* Stable output current of about 1 A
* Price
* Compact package
* Good and comprehensible documentation
* Solderability, at best by hand

Following these criteria, the onsemi MC34063ADR2G[[3]](#footnote-3) was deemed a good fit. Its relatively small package SOIC-8 is still solderable by a skilled hobbyist. The price tag is cheap enough to allow for iterating without straining a private budget too much. And most importantly, the documentation already contains a reference circuit with a variable 15 to 25 V input and a stable 5 V output.

Additionally, searching for MC34063 will yield many alternative options from different suppliers and manufacturers in case, sourcing the onsemi chip will become difficult in the future.

To calculate the passive components, some basic values have to be calculated in advance. All calculations are done according to Texas Instruments *Basic Calculation of a Buck Converter's Power Stage*[[4]](#footnote-4).

Duty Cycle D

Note: Efficiency η is chosen as a good guess according to reference document 4 suggestion.

Switching Frequency fs with a given timing capacitor of 470 pF

### Dimensioning of passive components

Calculation and selection of passive components according to referenced documents 3 and 4.

#### Inductor

The inductor needs an inductance of 220 µH according to MC34063ADR2G datasheet.

To calculate the overall current load of the inductor, it is first necessary to know the ripple current ΔIL

With the ripple current it is now possible to calculate the maximum switch current ISW(max)

ISW(max) is the peak current, if all of the logic circuitry draws about 1 A combined. Both, the inductor and the rectifying diode, have to withstand this load.

The inductor of choice is the SDRI127-221MT made by LanTu Micro. According to its datasheet[[5]](#footnote-5), it can withstand a stable switching current of 1.16 A *(Temperature Rise Current)* with peaks up to 2 A *(Saturation Current)*.

Note: A high saturation current is especially important in a switch mode power supply like this. The inductor limits current flow through the diode until the saturation current is reached. After that, the current can rise exponentially, putting a very high strain on the diode.

#### Rectifying Diode

The rectifying diode is of great interest because it’s showing significant heating during operation.

For minimal power losses, the diode should feature a very low forward voltage, thus Schottky diodes are usually recommended.

In reference document 3 they use a diode of the type 1N5819. As a starting point, the same diode of the manufacturer KEXIN[[6]](#footnote-6) was chosen.

The forward current IF in the diode is equal to

The power loss in the diode PD is calculated by

The temperature rise of the diode during a maximum load event is expected to be

Though significant, the temperature rise should still be acceptable, since the diode can operate with junction temperatures up to 125 °C.

## Reverse Polarity Protection

Reverse polarity protection according to Texas Instruments reference sheet *Reverse Current/Battery Protection Circuits[[7]](#footnote-7).*

Implemented are both, a Schottky Diode or a P-Channel MOSFET for protection. It’s well understood, that a MOSFET grants a more sophisticated and energy efficient protection. However, a Schottky diode was also implemented as a backup solution, in case a suitable MOSFET isn’t readily available.

### Selecting MOSFET

In this section, the main selection criteria for a suitable MOSFET shall be explained. Following the criteria, one specific example is given.

Main selection criteria, ordered by priority:

* Low RDS(on) to increase power efficiency
* Small package due to space constraints
* Package shall be solderable by hand

The package type SOT-23 is small while keeping solderability by hand. Many types of MOSFETs are available in this package size. For this board iteration, the MOSFET SE3415[[8]](#footnote-8) by manufacturer SINO-IC was chosen.

Given the datasheet, it is possible to calculate the power loss during 1 A peak power consumption and temperature rise for both, the 3V3 and 5V rail.

All values are very low and should not be subject of concerns.

### Selecting Schottky Diode

In this section, the main selection criteria for a suitable MOSFET shall be explained. Following the criteria, one specific example is given.

Main selection criteria, ordered by priority:

* Low forward voltage to increase power efficiency
* Simplified Bill of Material

Note: Output voltage of the diode equals input voltage minus forward voltage. Therefore, a minimum forward voltage, especially on the 3V3 rail, is crucial to keep the rail within tolerance margin!

Mostly for a simplified bill of material, the same Schottky diode as in the buck converter was chosen. Therefore, document 6 should be consulted for technical specification.

A quick check of the diode power shows a power loss of about 0.5 W at 1 A peak power consumption.

The power loss should lead to a temperature rise of about 44 °C. This is significant but acceptable, since the operating junction temperature according to reference document 6 can be as high as 125 °C.

It is very obvious, that the MOSFET solution is 14 times as efficient and heats up 19 times less as the diode solution.

# High Power Externals

## MOSFETS

### Selecting IC

N-Channel due to more common use and thus ease of use

Very low RDS(on) for minimum power loss during current surge events

Very small package due to space constraints on PCB

High power dissipation

### Switch Layout on PCB

High side switch

### Dimensioning of passive components

Charging of parasitic gate capacitance cannot exceed maximum output current of analogue multiplexer CD4051BM96[[9]](#footnote-9).

# Internals

## Multiplexers

### Selecting IC

### Dimensioning of passive components

# PCB

## Buildup

## Special Layout Features

## Dimensioning of high current paths

1. <https://www.onsemi.cn/download/data-sheet/pdf/nis4461-d.pdf> [↑](#footnote-ref-1)
2. <https://www.onsemi.com/pub/Collateral/AND9441-D.PDF> [↑](#footnote-ref-2)
3. <https://www.onsemi.com/pdf/datasheet/mc34063a-d.pdf> [↑](#footnote-ref-3)
4. <https://www.ti.com/lit/an/slva477b/slva477b.pdf> [↑](#footnote-ref-4)
5. <https://datasheet.lcsc.com/lcsc/2208161630_LanTu-Micro-SDRI127-221MT_C5127291.pdf> [↑](#footnote-ref-5)
6. <https://datasheet.lcsc.com/lcsc/1912111437_KEXIN-1N5819_C437199.pdf> [↑](#footnote-ref-6)
7. <https://www.ti.com/lit/an/slva139/slva139.pdf> [↑](#footnote-ref-7)
8. <https://datasheet.lcsc.com/lcsc/2208251800_SINO-IC-SE3415_C238680.pdf> [↑](#footnote-ref-8)
9. <https://www.ti.com/lit/ds/symlink/cd4051b.pdf> [↑](#footnote-ref-9)