My Components Choice:

Arduino nano33 iot controls following components:

4 Trimmer Resistors -> Digital Potentiometers

3 Switches -> Digital or Analog Switches

Slide Rheostat for Load -> Rotary Rheostat with Servo Motor

RV1~4 Requirements:

Voltage across RV1 = 0~1V; Max current = 0.05 mA.

Voltage across RV2 = 0~2V;

Voltage across RV3&4 = 0~4V; Max current = 0.2 mA.

RV1 & RV2 (2.22KΩ)

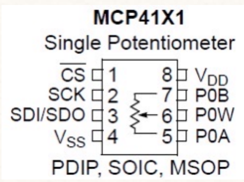
- MCP4151-502E/P Volatile Digital Potentiometer, 5kΩ, Single, SPI, Linear
  Single 257-tap Volatile Digital Pots (8 bits)

RV3 & RV4 (50KΩ)

- MCP4151-503E/P Volatile Digital Potentiometer, 50 kΩ, Single, SPI, Linear
  Single 257-tap Volatile Digital Pots (8 bits)

Device Specifications:

MCP4151-503E/P Volatile Digital Potentiometer, Single, SPI, Linear



Resistance options: 5kΩ, 10kΩ, 50kΩ, 100kΩ with 8 bits resolution.

Operating range Vdd = 2.7~5.5V

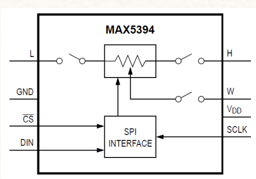
Resistor terminal input voltage range (VA, VB, VW) = Vss~Vdd

Max resistor terminal current through = 2.5 mA

Continuous power dissipation = 400 mW

Device specifications:

MAX5394 Volatile Digital Potentiometer, Single, SPI, Single 256-tap (8 bits)



Resistance options: 10kΩ, 50kΩ, 100kΩ with 8 bits resolution.

Operating range Vdd = 2.6~5.5V

Resistor terminal input voltage range (VH, VL, VW) = Vss~Vdd

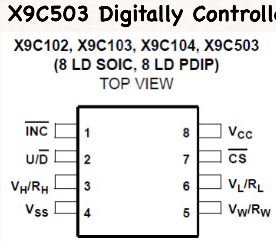
Max resistor terminal current through (50kΩ) = 2 mA

Continuous power dissipation = 953.5 mW

This device is out of stock and 10kΩ is not a good solution for 2.2kΩ.

Device Specifications:

X9C503 Digitally Controlled Potentiometer, Resistor Array, Non-volatile Memory



Resistance options: 1kΩ, 10kΩ, 50kΩ, 100kΩ with 100 wiper tap points.

Operating range Vcc = 5V

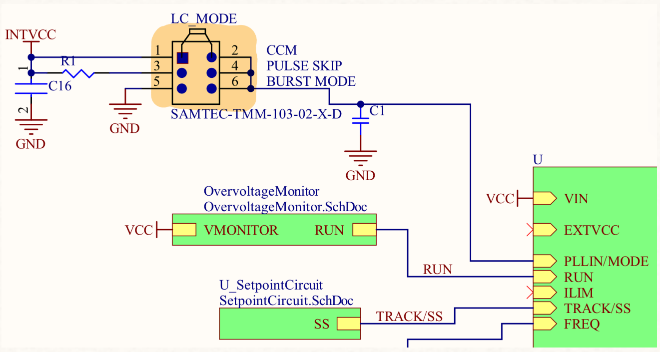
Max resistor terminal voltage difference (VH-VL) = 4V for 1kΩ & 10V for other versions

Max resistor terminal current through = 8.8 mA

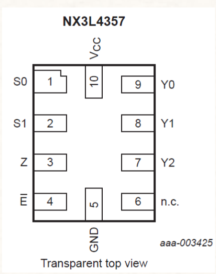
Power rating = 16 mW for 1kΩ version & 10 mW for others

This device has low resolution (not elegant - 99 resistive elements in an array),
and not good as a 2.2kΩ solution.

LC_MODE switch requirements:
PLLIN/MODE pin determines operation mode
Burst Mode: PLLIN/MODE pin connected to SGND;
Forced continuous: PLLIN/MODE pin connected to INTVcc;
Pulse-skipping: PLLIN/MODE pin connected to (INTVcc-1.3V) > & > 1.2V.
Voltage at PLLIN/MODE pin = 0~5.2V
Basically no current go through (DC voltage).
LC_MODE Switch
- TS5A3359 1Ω SP3T Bidirectional Analog Switch

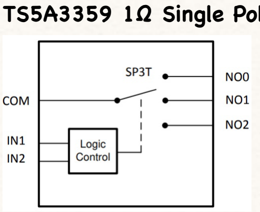


Device Specifications:
NX3L4357 Low-ohmic Single Pole Triple Throw



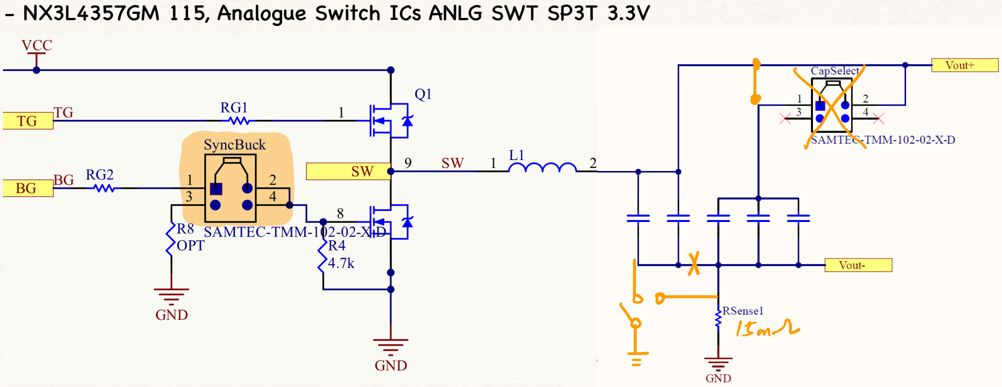
Supply voltage range = 1.4~4.3V
Signal with amplitude up to Vcc to be transmitted from Z to Yn or Yn to Z terminal.
Continuous current under 3.3V supply = 350mA
ON resistance = 0.5Ω
Maximum voltage is limited by 4.3 V, which is not suitable for switching to INTVcc (5.2V) connection.

Device Specifications:
TS5A3359 1Ω Single Pole Triple Throw, Bidirectional Analog Switch

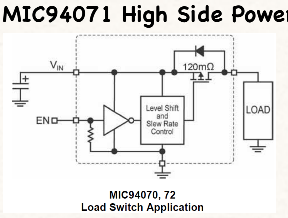


Supply voltage range = 1.65~5.5V
Voltage at COM or NO = -0.5~(Vcc+0.5) V
On-state switch current through COM = ±400 mA; through NO = ±200 mA
(when voltage at COM or NO = 0 to Vcc)
ON resistance = 1Ω

SyncBuck Switch Requirements:
Frequency: 320k~2.25MHz
1&2 shorted: 0~5.2V square wave
3&4 shorted: -1V~1V periodic wave
CapSelect Switch Requirements:
If place this switch between Vout+ and Vout-, the voltage drop of the switch will effect the output performance.
Instead place CapSelect switch between Vout- and GND, in order to select path for different capacitance value.
Original circuit has 0.015Ω resistance Rsens1 between Vout- and GND, which has 10~20mV & 0.67~1.33A.
Thus voltage and current across the switch depends on On-state resistance.
SyncBuck Switch & CapSelect Switch
- NX3L4357GM 115, Analogue Switch ICs ANLG SWT SP3T 3.3V

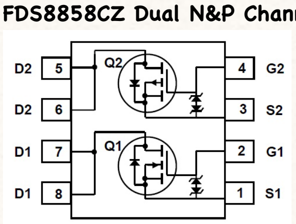


Device Specifications:
MIC94071 High Side Power Switches - Load Switch Application



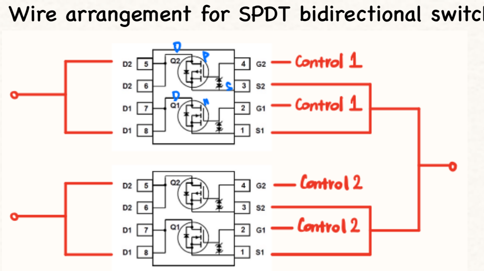
Single P-channel MOSFET
Input voltage range = 1.7~5.5V
Continuous operating current Id = 1.2A & Pulse current = 3A
Max on-state drain to source resistance = 285 mΩ
Turn off resistance = 200~400 Ω
This device does not support bidirectional current.

Device Specifications:
FDS8858CZ Dual N&P Channel MOSFET



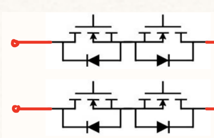
Dual operation power dissipation = 2W
N-channel MOSFET:
Max Vds = 30V; Max Vgs = 20V Max continuous Id = 8.6A
Max Rds_on = 20mΩ when Vgs = 4.5V & Id = 7.3A
P-channel MOSFET:
Max Vds = -30V; Max Vgs = 20V Max continuous Id = -7.3A
Max Rds_on = 34.5mΩ when Vgs = -4.5V & Id = -5.6A

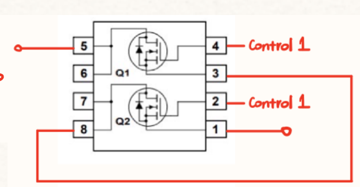
Wire arrangement for SPDT bidirectional switch:



However, Arduino pin cannot provide negative gate voltage to turn on P-channel MOSFET, otherwise an inverse amplifier should be implemented to inverse the voltage.

Device Specifications:
FDS9926A Dual N Channel MOSFET





Gate drive voltage Vgs = 2.5~10V
Max drain-source voltage Vds = 20V
Max continuous drain current Id = 6.5A
Dual operation power dissipation = 2W
Rds_on = 43mΩ when Vgs = 2.5V & Vds = 20V & Id = 6.5A

Controllable Load Resistance Requirements:

Load voltage = 0~7V

Load current = 0~5A

Max load power = 35W

Load resistance: need high resolution at 0-5Ω (resolution ≤ 0.2Ω for capture load current 3A, 3.5A, 4A)

Max range ≥ 33Ω (33Ω is the threshold for continuous mode and discontinuous mode)

Iout/A	Vout/V	Rload/Ω	Pin/W	Pout/W	Efficiency
0.51	3.25	6.38	2.2	1.66	0.755
1.04	3.19	3.07	3.97	3.32	0.836
1.53	3.24	2.11	5.72	4.95	0.865
2.02	3.32	1.64	7.67	6.7	0.874
2.53	3.29	1.30	9.54	8.33	0.873
3.07	3.25	1.06	11.48	9.98	0.869
3.55	3.27	0.92	13.42	11.6	0.864
4.1	3.29	0.80	15.8	13.49	0.854

Approach 1: Digital potentiometer as load resistance.

Resistance Requirement:

From Buck converter lab course, the load current should ramp up to 4A (5A is a max for load current). The graph shows load resistor variant range for 0-4A load current. As digital potentiometer minimum resistance is limited by wiper resistance - around 60 Ohm, a few ohm resistance can not be achieved by digital potentiometer.

(Smallest digital potentiometer found: X9C102 - 1K Ohm)

Power Handling Capability:

The load resistance consume high power 13.5W for 4A&3.3V output. Max output power can be up to 35W. Digital potentiometer only has mW power rating.

Conclusion: Digital potentiometer cannot be used as a dummy load for this buck converter.

Approach 2: Rheostat as load resistance with a servo motor.

It is easy to find a high power low resistance shaft potentiometer (50W & 30 Ohm wire wound ceramic potentiometer).

It is also easy to find a rotation servo motor (6V analog continuous rotation servo motor)

Arduino has a very traitor forward function to write to servo (rotate 0-360 degree)

- SER0044 270 degree Rotation Micro Servo 15KG*cm at 7V supply
- 50W 20R Ohm Wirewound Ceramic Potentiometer Variable Rheostat Resistor with Knob

Conclusion: This is the simplest way to build a remote control resistance variable dummy load.

But at high power, how hot is the shaft potentiometer?

How to mount the servo motor with the shaft potentiometer? (mechanical structure; material; torque; fan or heat sink; temperature sensor for temperature monitor and fan control; etc)

Approach 3: Switching a bank of fixed resistors.

Resistance Requirement & Power handling capability:

Power film resistor: MP9100 TO-247 Kool-Pak has following resistance values

& 100W continuous power rating at 25 degree case temp with heat sink

Standard Resistance Values:

Tolerance: 1% Standard

0.050 Ω	0.50 Ω	3.90 Ω	25.0 Ω
0.10 Ω	0.75 Ω	5.00 Ω	27.0 Ω
0.12 Ω	1.00 Ω	8.00 Ω	33.0 Ω
0.15 Ω	1.50 Ω	10.0 Ω	39.0 Ω
0.20 Ω	2.00 Ω	12.0 Ω	47.0 Ω
0.25 Ω	2.20 Ω	15.0 Ω	50.0 Ω
0.30 Ω	2.50 Ω	18.0 Ω	56.0 Ω
0.33 Ω	3.00 Ω	20.0 Ω	75.0 Ω
0.39 Ω	3.30 Ω	22.0 Ω	100 Ω

Switch design:

This lab course requires high resolution at small values, which makes the circuit for connecting fixed resistors complicated.

The load resistance range is hard to make continuous and log scale.

The switch still has the problem of voltage drop, which will impact output current and voltage of the load.

Conclusion: A bank of fixed power resistor requires complex switch circuit design, and too many switches.

Suffer problem of voltage drop, effecting load performance.

Power dissipation - heat sink design - temperature monitor

Discontinuous resistance range

Approach 4: Voltage controlled resistor based on JFET.

- UF3N170400B7S 1700V-400mΩ Sic Normally-on JFET

Rds_on = 400 mΩ

Max drain source voltage = 1700V

Max continuous drain current = 6.8 A at 25°C; 5.1A at 100°C

Power dissipation = 68W

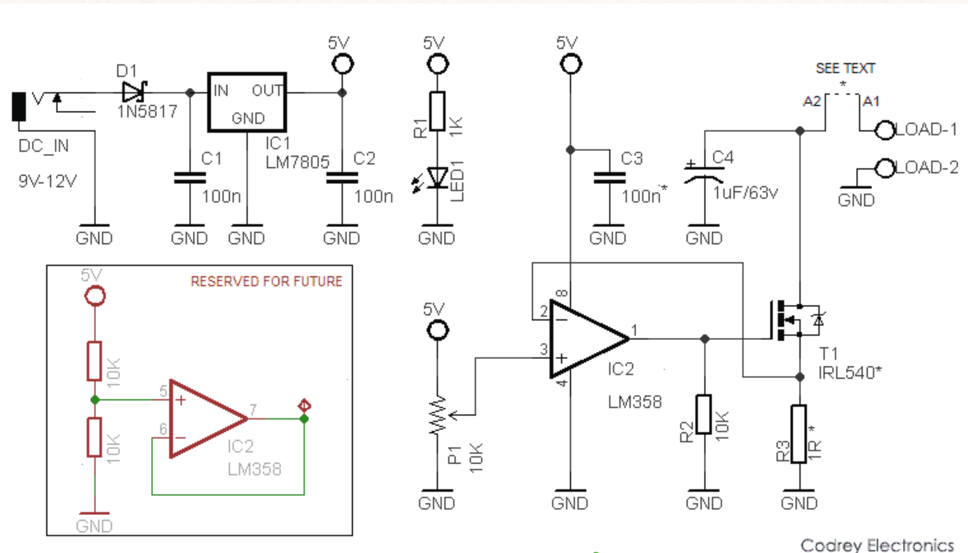
electrical energy
heat dissipate ⇄ temperature
speed. ↑

Approach 5: Electric Load (Power MOSFET as Load).

Control gate voltage of power MOSFET (T1) to control current through it, regardless voltage across it. (Heat sink needed)

This can imitate a resistive load for the buck converter.

The control voltage is set by the potentiometer (P1), with feedback control from unity amplifier and current sense resistor.



how quickly the temp raised.
→ calculated.
→ Heat sink – order
current – resistor.
Hot cerame
metal thim
→ approximations.
→ order of magnitude
how big.
or do we need a fan

Max power
until conventor shut down

Rth [k/W]
Steady state → constant heat
too small → tem keep raising
big → stop

① more information electric load
athoritcaten
(application load)
textbook / journal /
how they work (efficitive)

② Spice simulation

③ Build the circuit (circuit example)

④ Higher current version.
one thing at a time, build it & measure it