Expt 1 – DC Power Supply

EE 230 Analog Circuits Lab

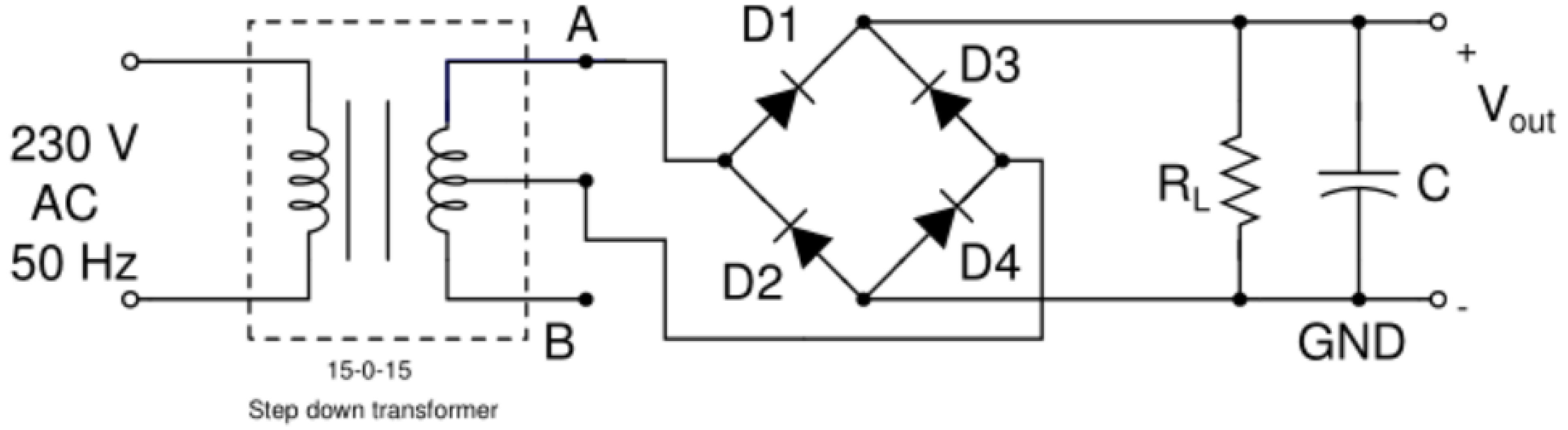
Credits: Prof. Joseph John

2021-22/2

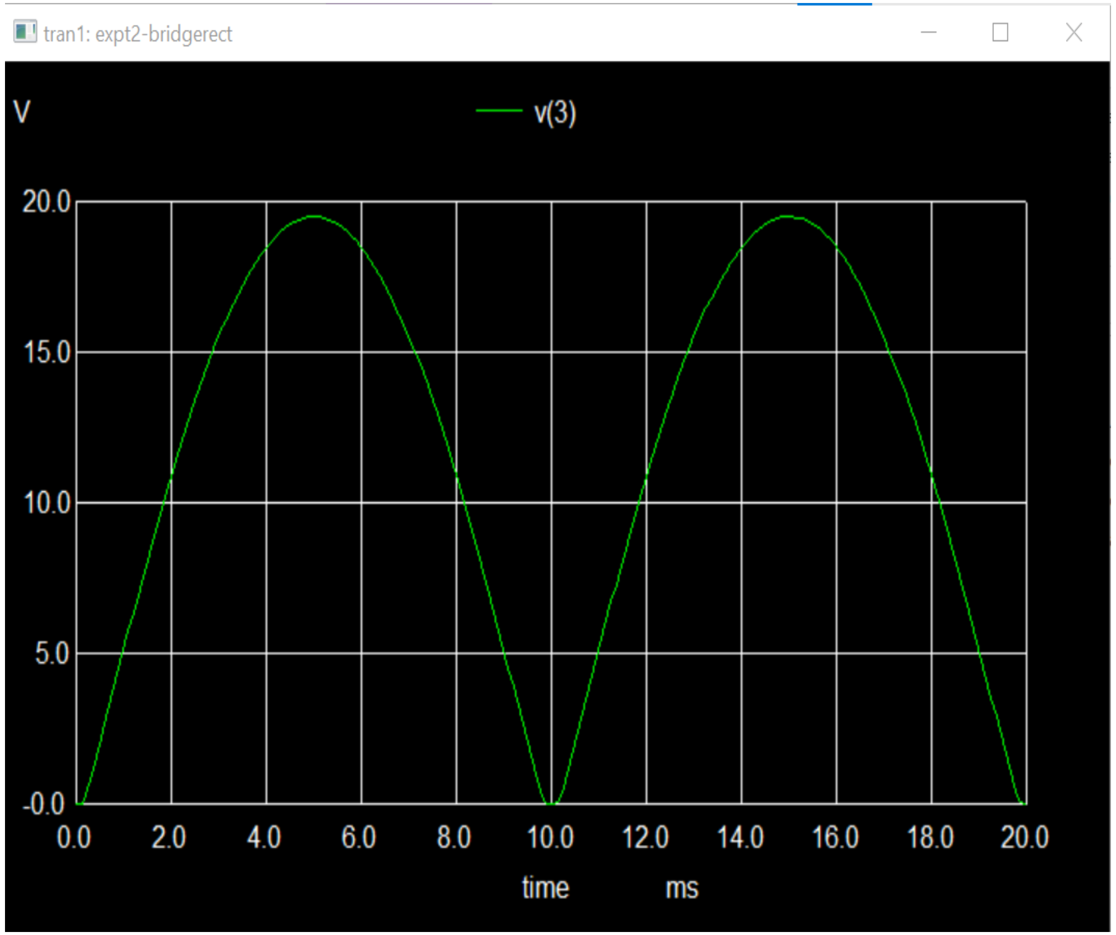
Major Sections

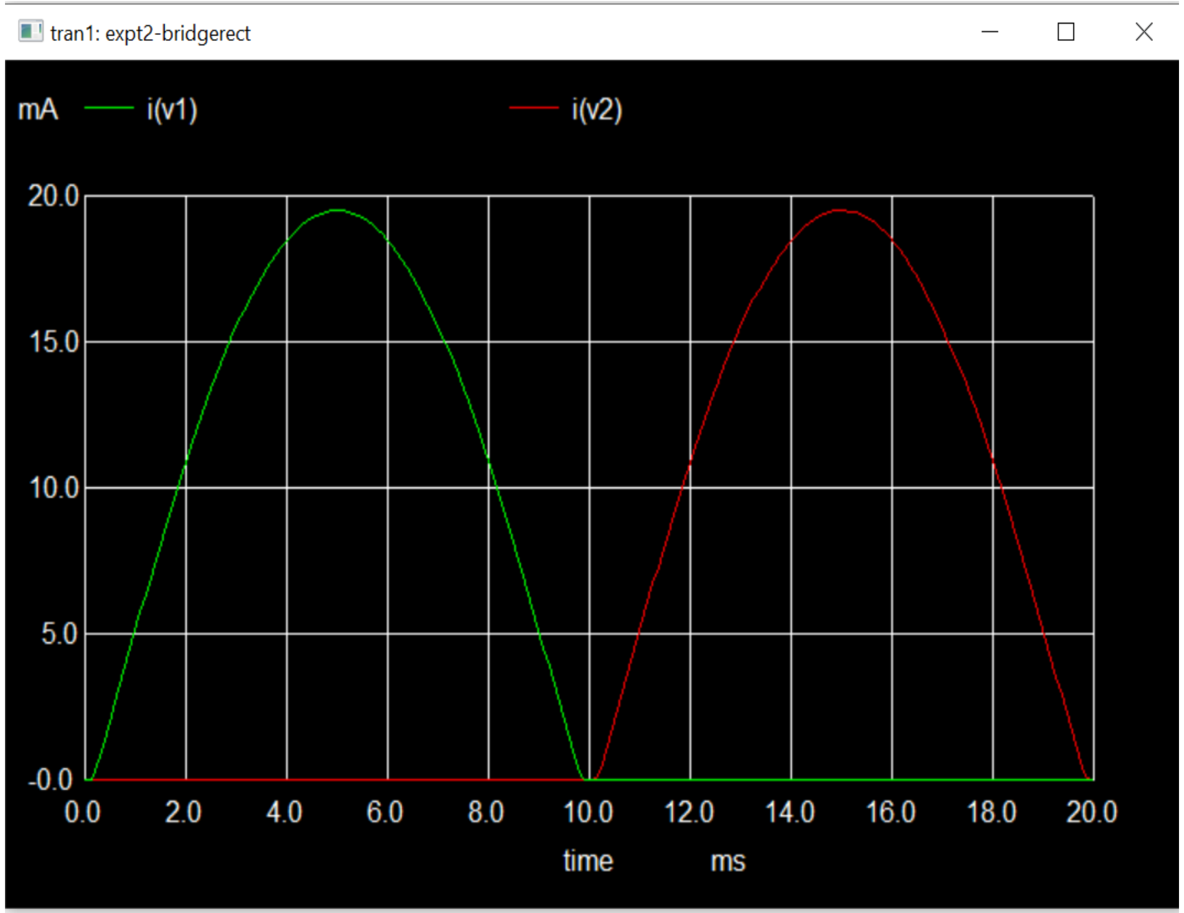
- Part A – Unregulated Power Supply (with Capacitive Filter)
- Part B – DC Power Supply with Zener Diode Regulator
- Part C – DC Power Supply with a BJT Series Regulator

Part A – Unregulated Power Supply (with Capacitive Filter)



Full wave rectifier

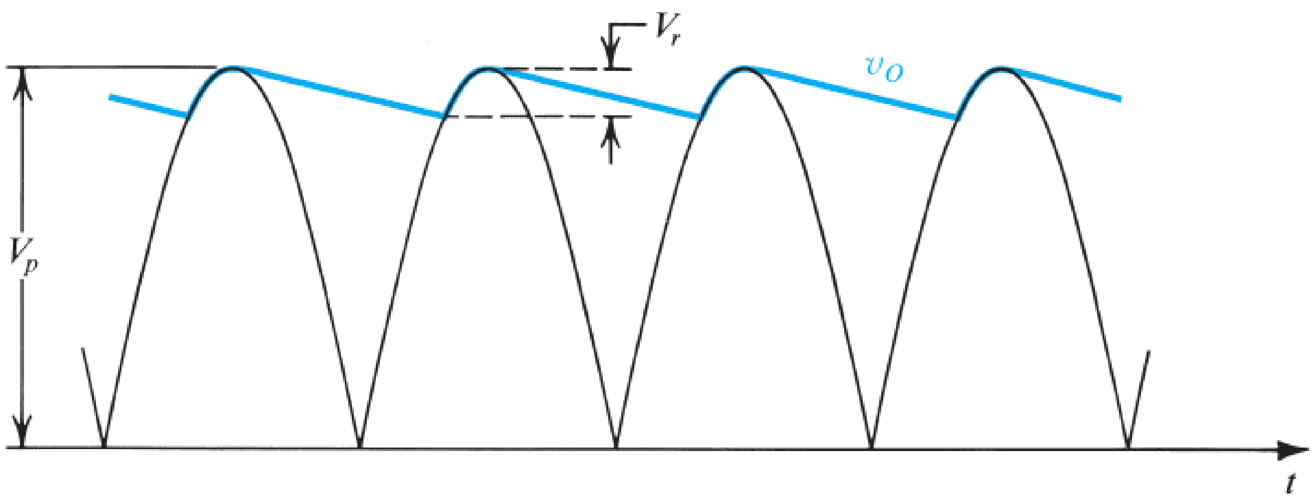




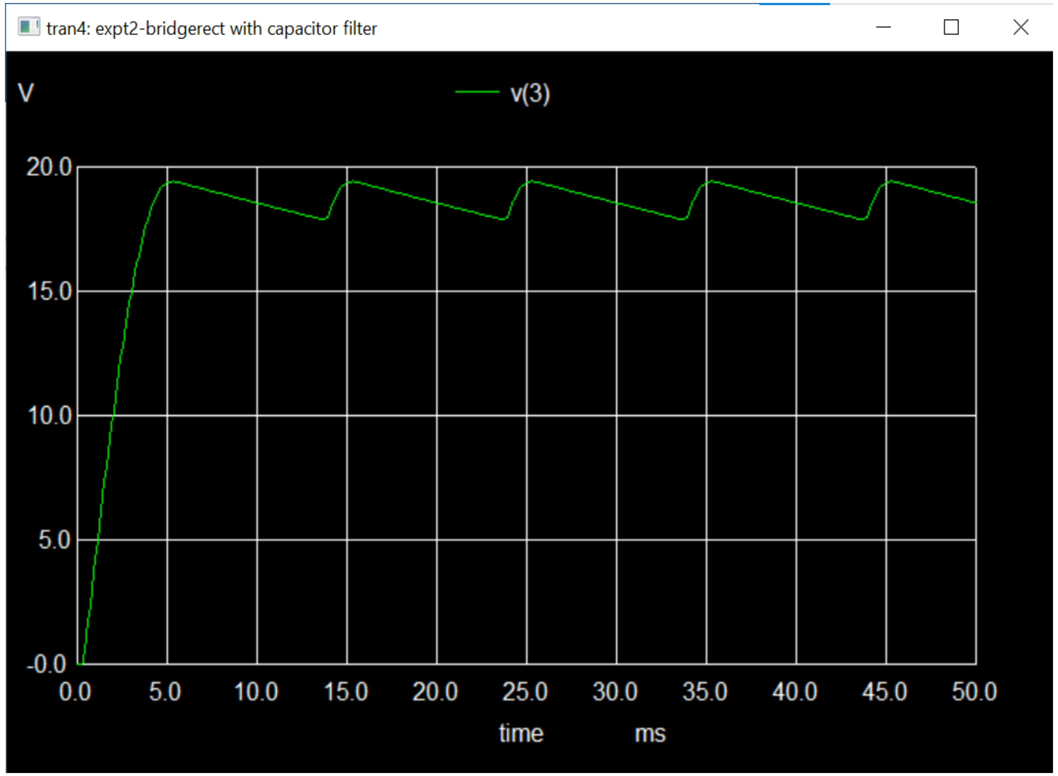
Output voltage, V_{out}

Load current, I_L

Full wave rectifier (Bridge rectifier) Waveforms – without C



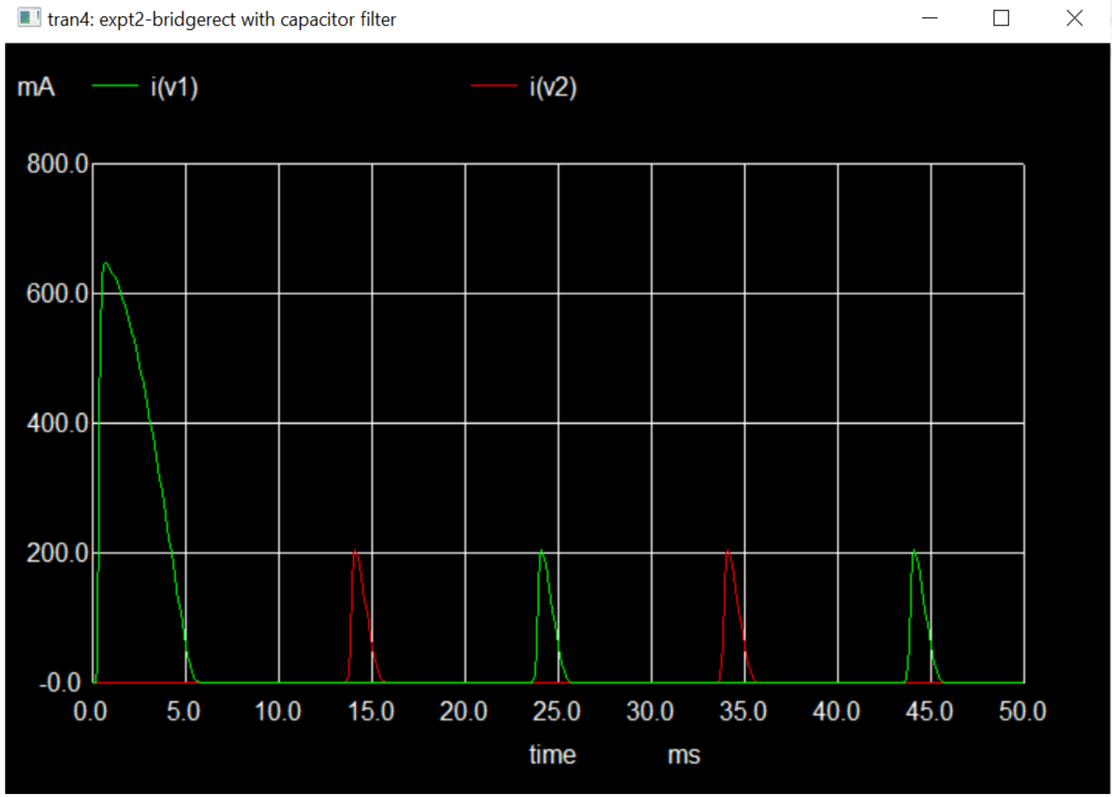
$C = 100\ \mu F$, $R_L = 1\ k\Omega$

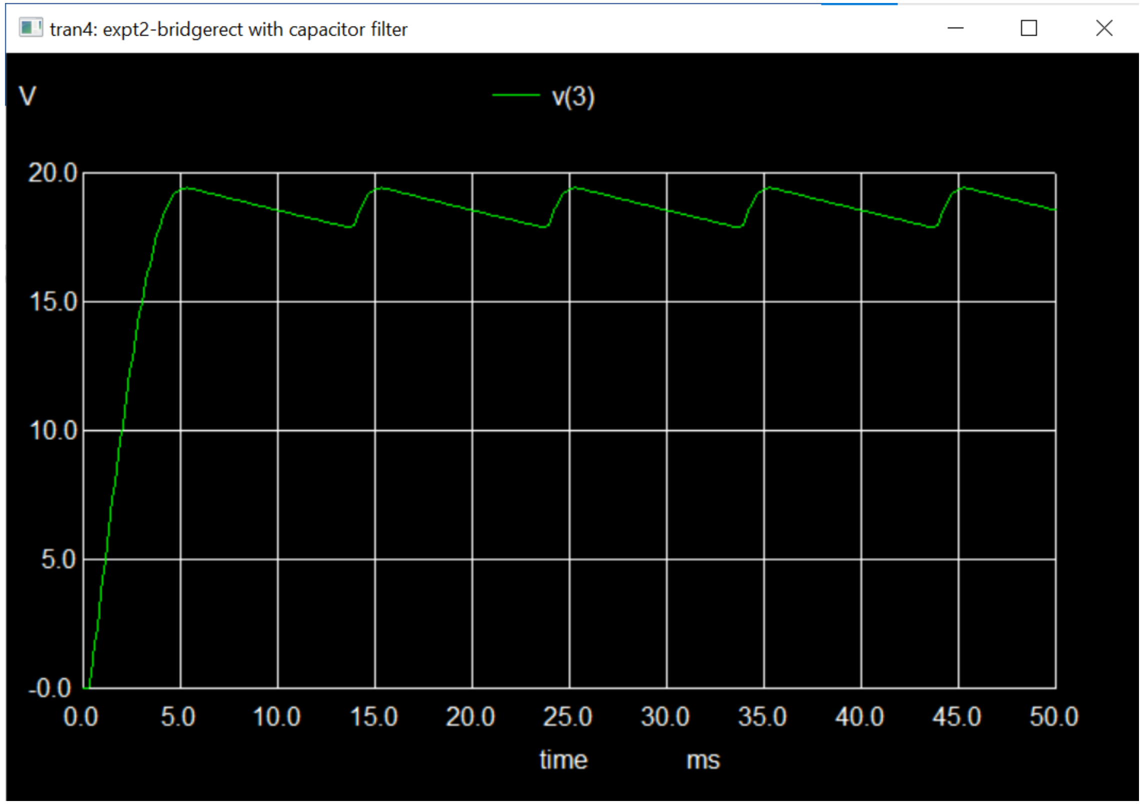


- Full-wave rectifier output waveform (blue)
- Less Ripple voltage, compared to a (Half-wave rectifier)
  - Discharge interval for C almost half that of HW case)

Effect of Capacitor Filter (on Vout and Diode Currents)

$C = 100\ \mu F, R_L = 1\ k\Omega$

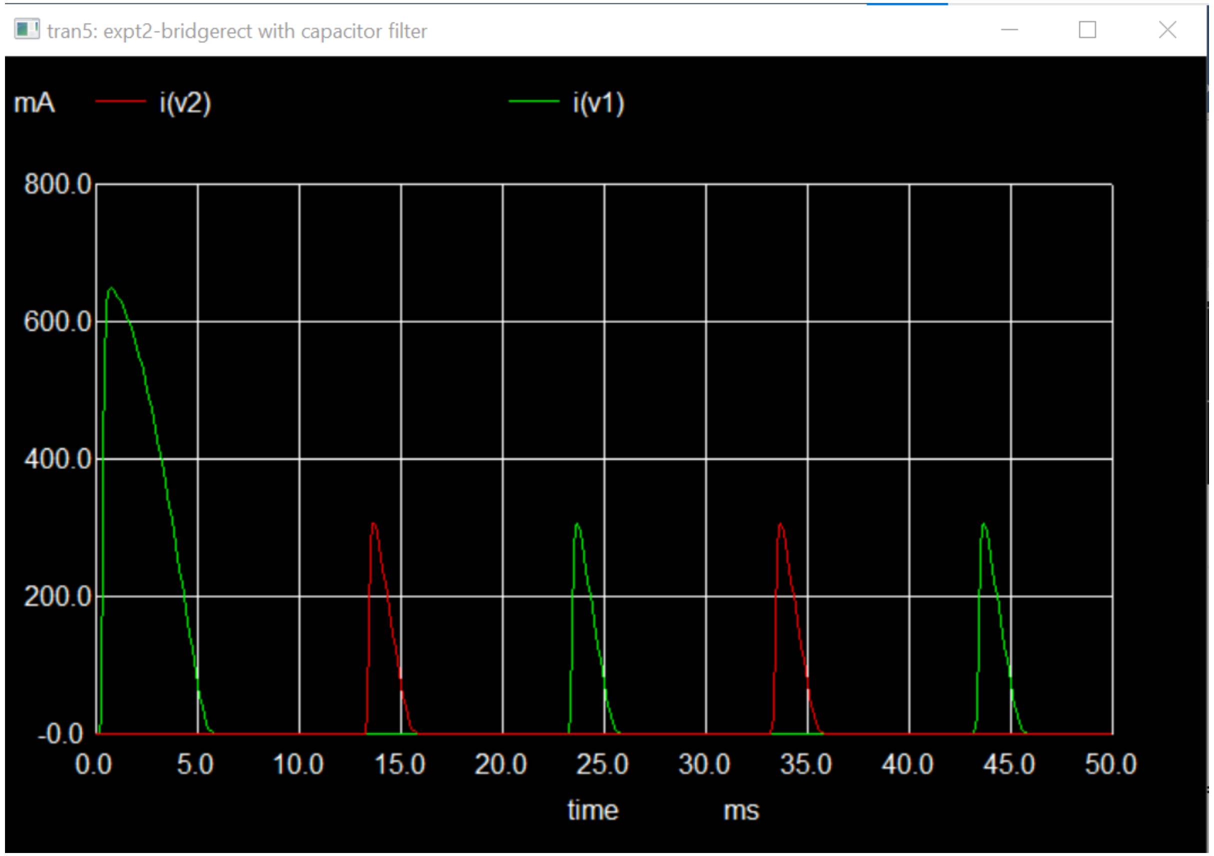


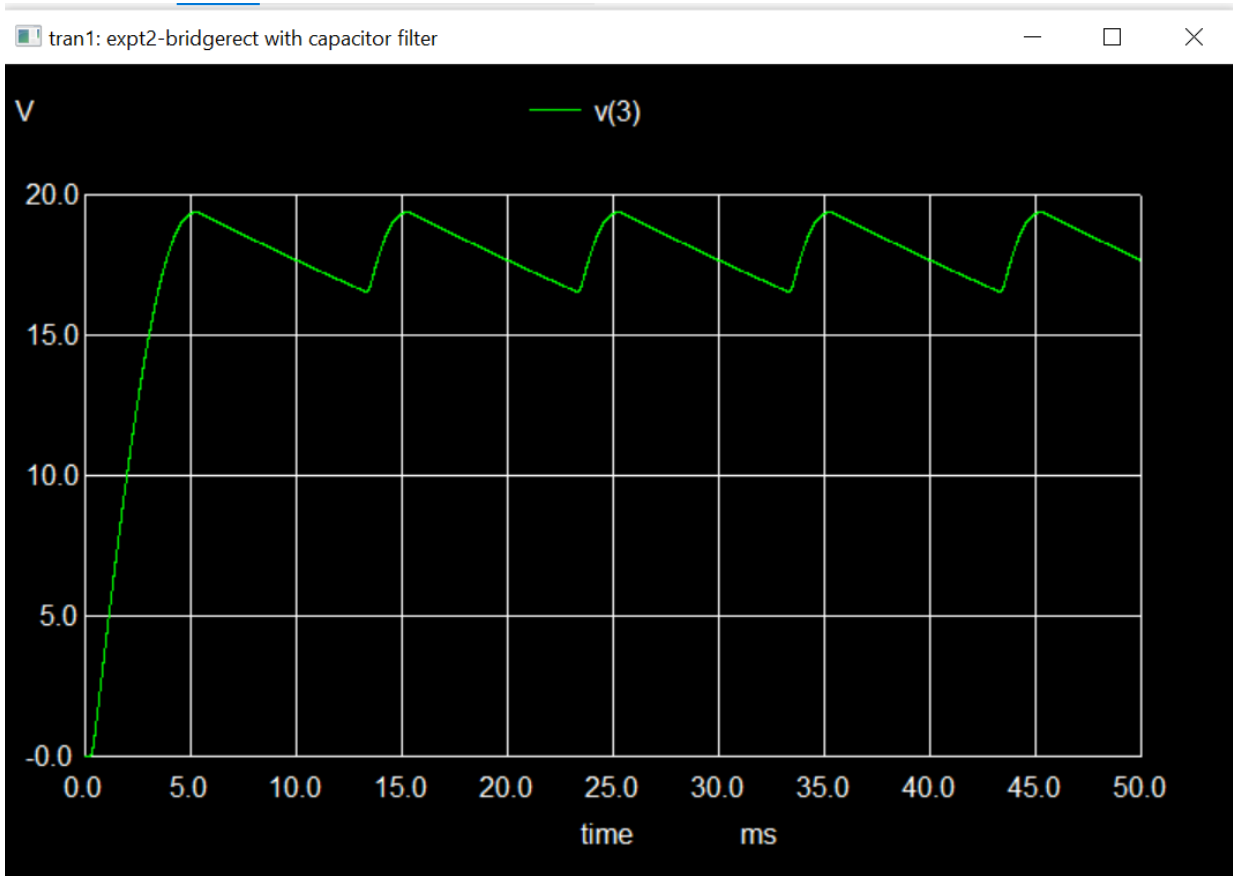


I_L (avg) $\approx$ 18.5 mA, $I_{Diode\text{-}peak} \approx$ 200 mA

Vout (avg) $\approx$ 18.5 V, $V_{p\text{-}p\ ripple}$ = 2 V

$C = 100\ \mu F$, $R_L = 500\ \Omega$

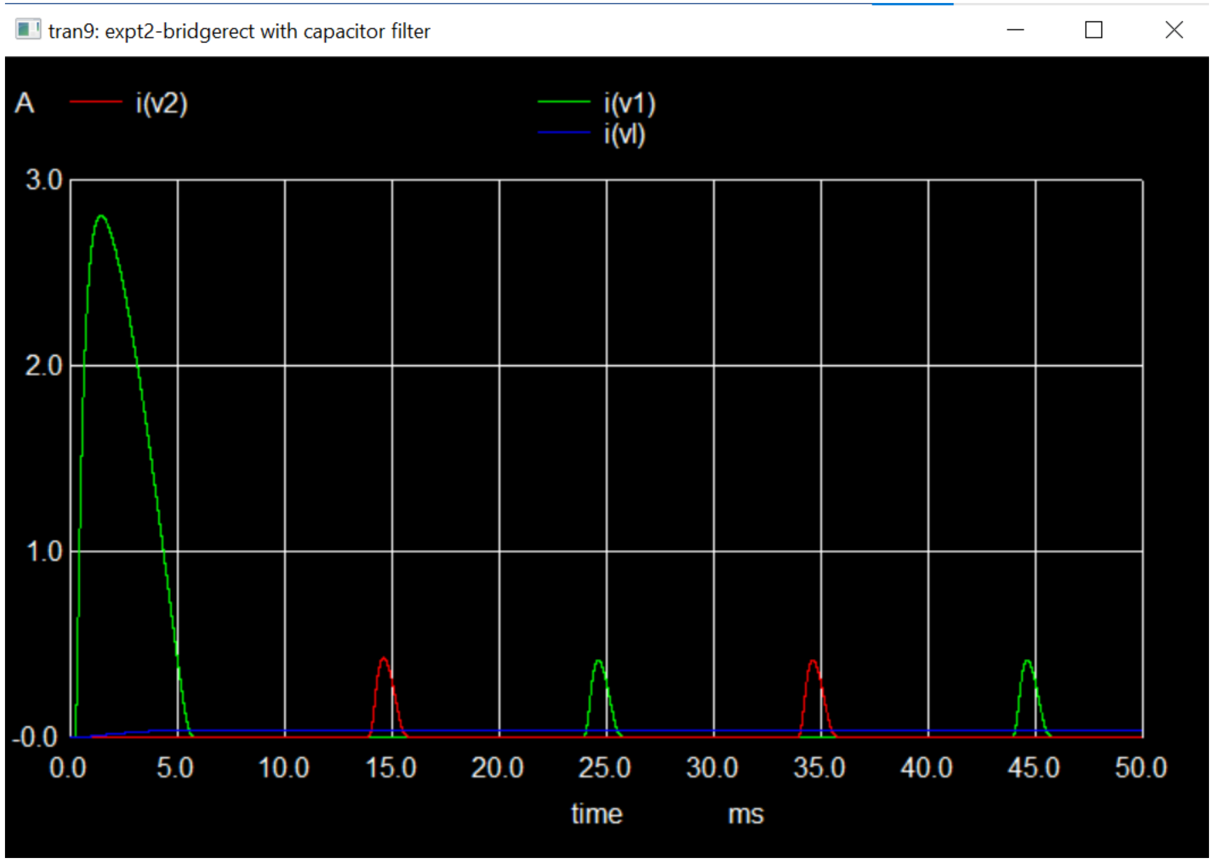


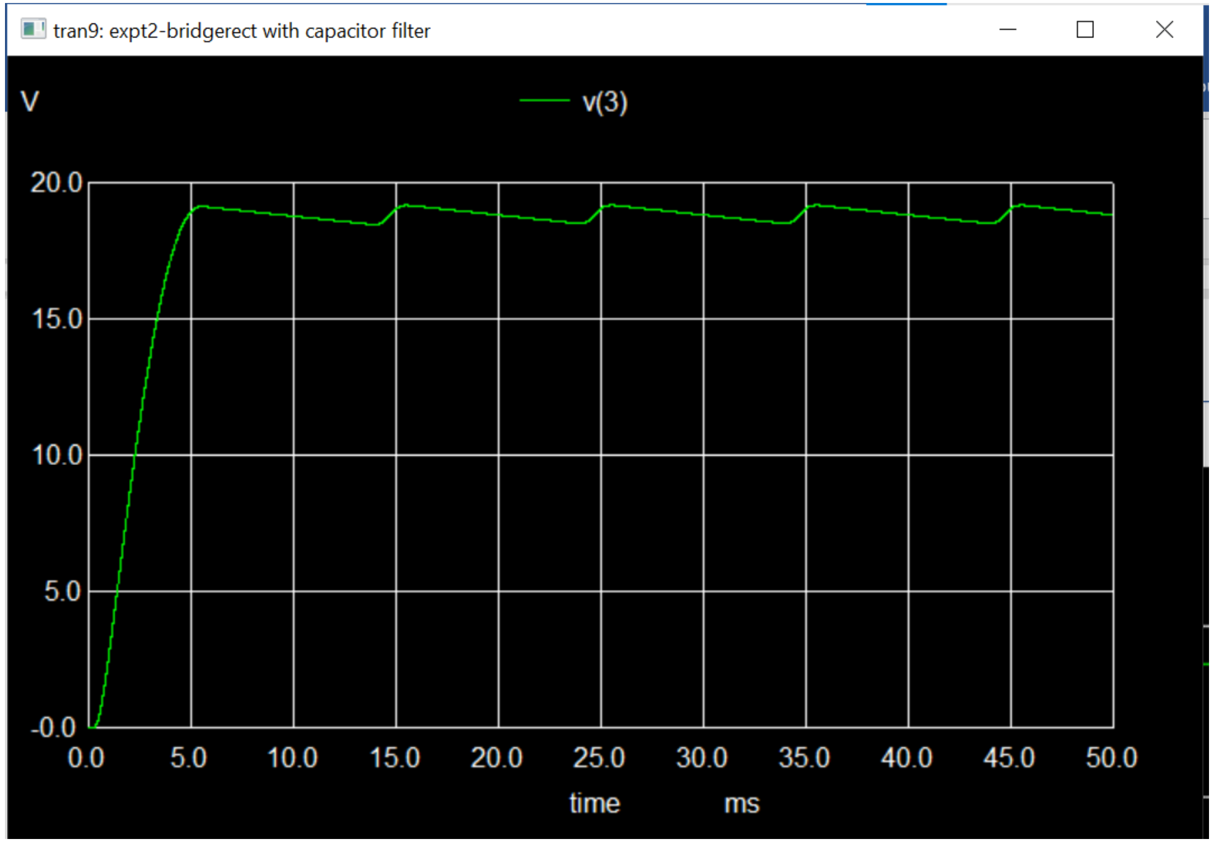


I_L (avg) ≈ 35 mA, $I_{Diode\text{-}peak}$ ≈ 300 mA

Vout (avg) ≈ 17.5 V, $V_{p\text{-}p\ ripple}$ = 3 V

$C = 470\ \mu F$, $R_L = 500\ \Omega$

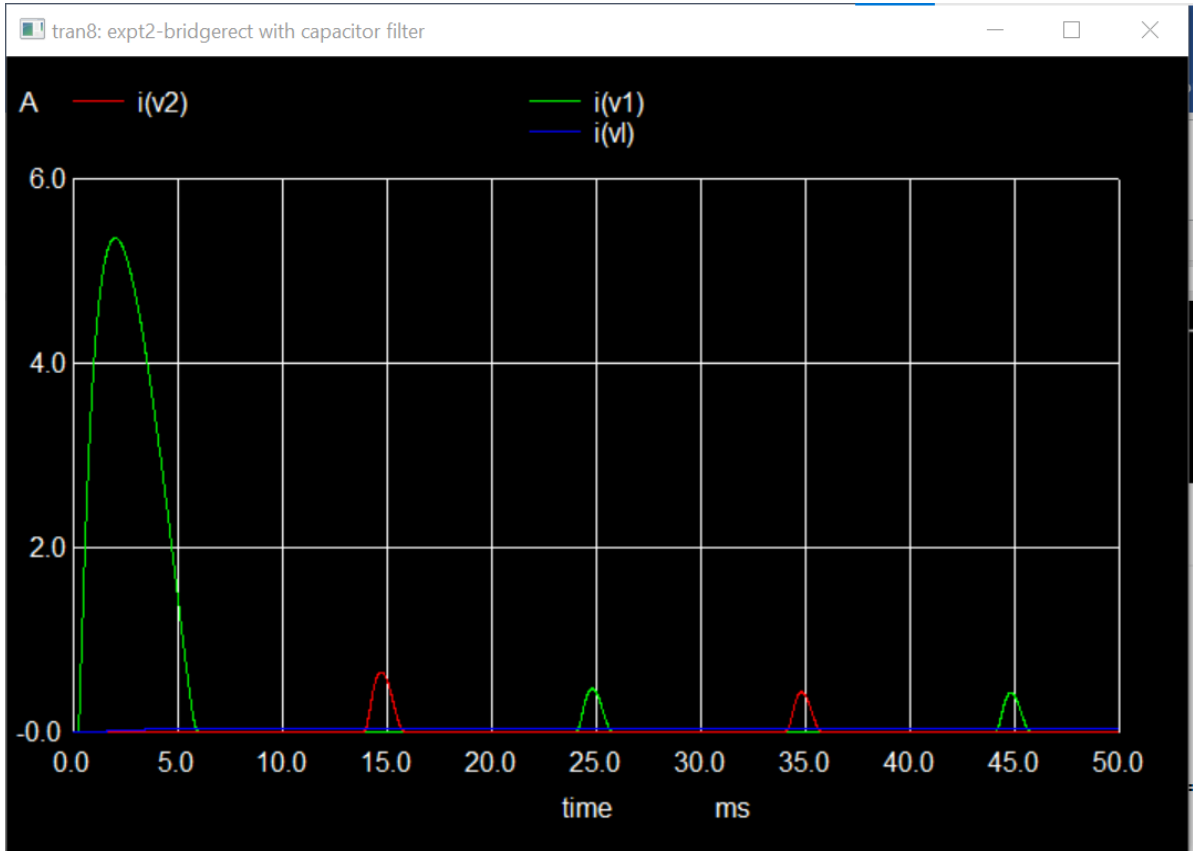


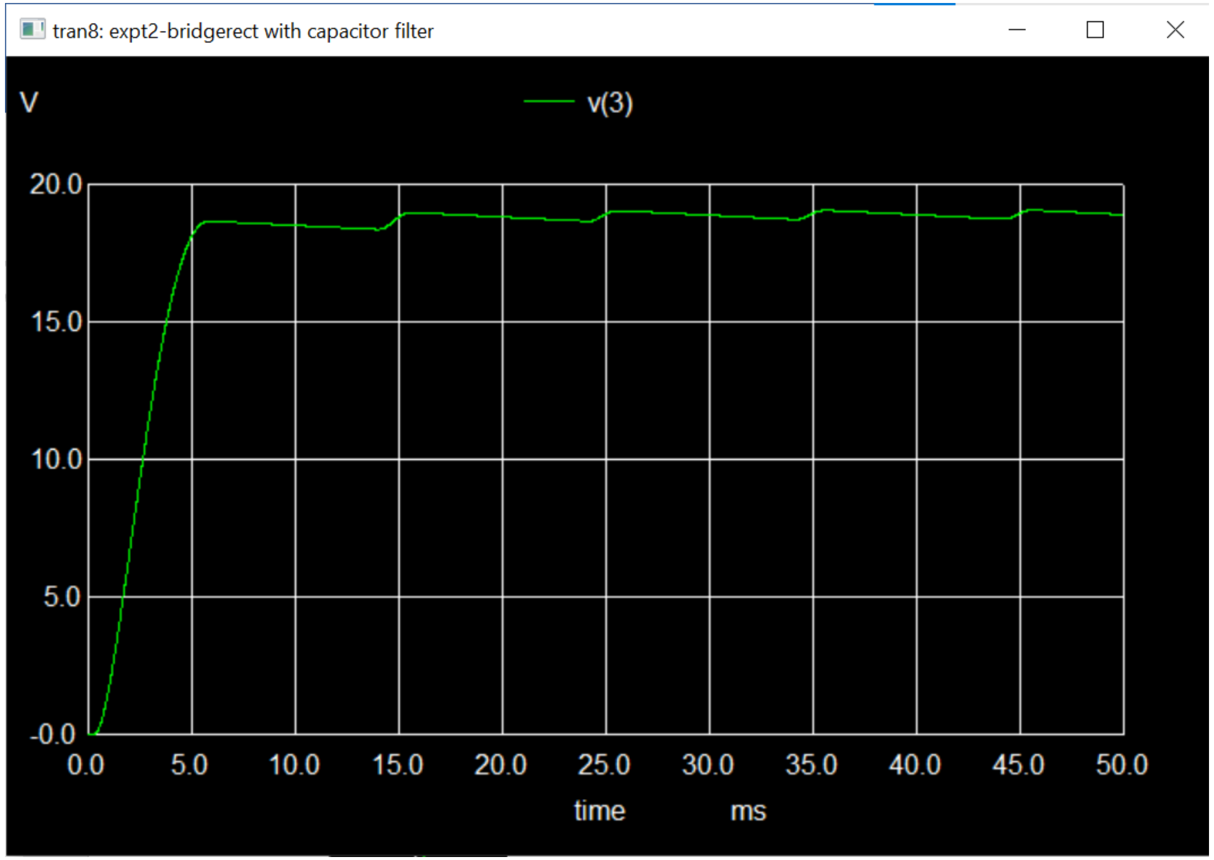


I_L (avg) ≈ 37 mA, $I_{Diode\text{-}peak}$ ≈ 400 mA

Vout (avg) ≈ 18.5 V, $V_{p\text{-}p\ ripple}$ = 1.5 V

$C = 1000\ \mu F$, $R_L = 500\ \Omega$





I_L (avg) ≈ 37.5 mA, $I_{Diode\text{-}peak}$ ≈ 500 mA

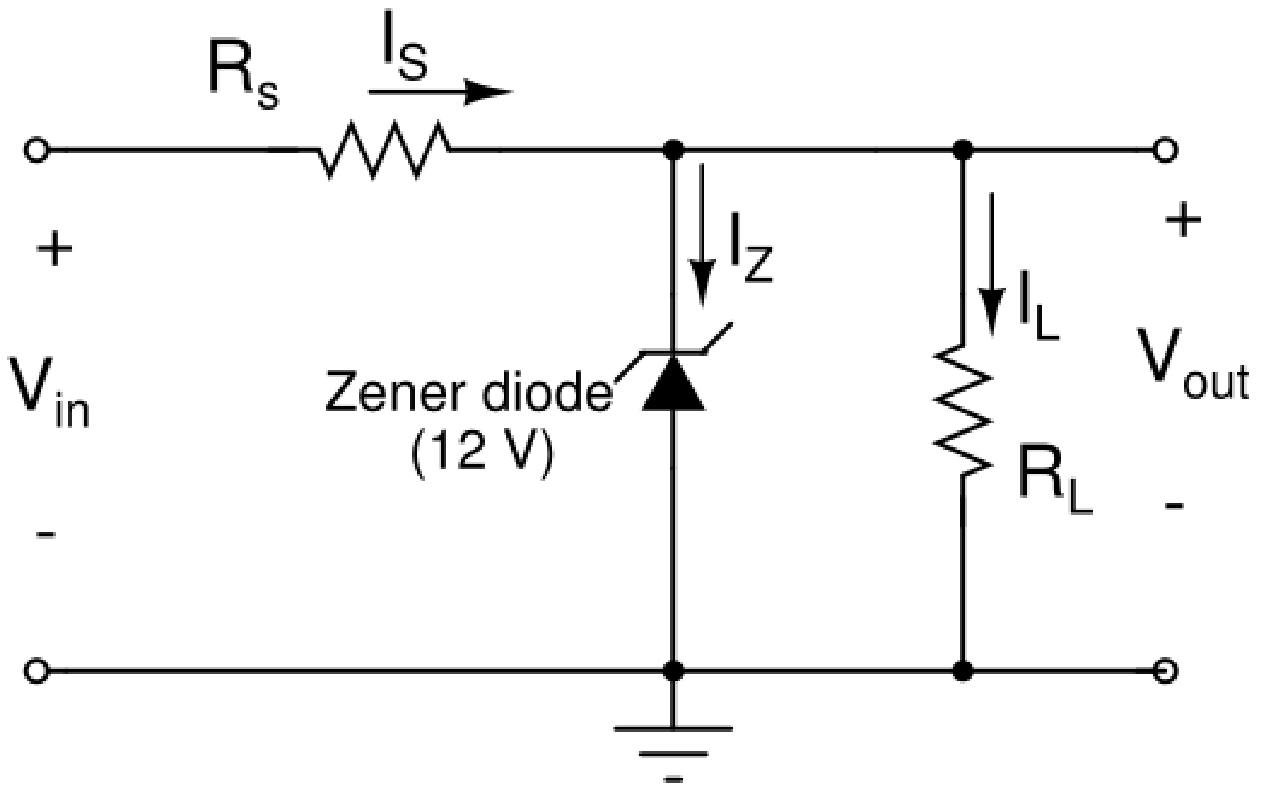
Vout (avg) ≈ 18.75 V, $V_{p\text{-}p\ ripple}$ = 1 V

Problems of an Unregulated Power Supply

- Output voltage fluctuates
  - When ac input voltage fluctuates
  - When load current fluctuates

- Ripple voltage increases with load current
  - Ripple voltage for a given load current (i_L) can be reduced only by increasing C
  - Increasing C beyond a certain value can cause diode damages (as the peak diode current will always be many times the average load current)

Part B – DC Power Supply with Zener Diode Regulator



- Design mainly involves choice of R_S
- Choose R_S based on I_Z, I_L and $V_{in,}$ as well as Vin and I_L variations

Zener Regulator – Experiment and NGSPICE Simulations

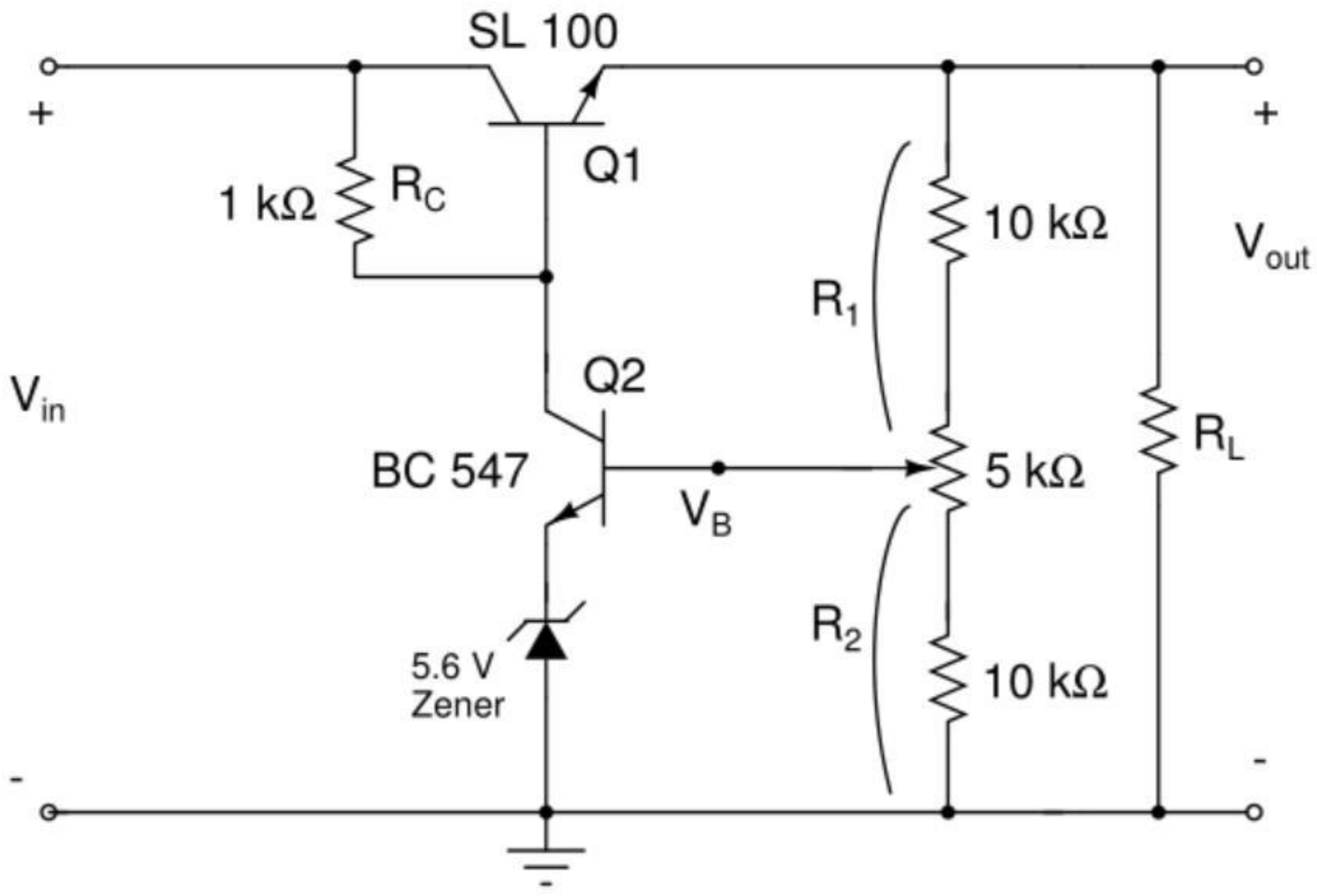
Zener Regulator		
RS=470		Offset=10.8V
RL=1k		rz=125ohms
	Expt	NGSPICE
Vin	Vout	Vout
15	10.14	10.20
16	10.87	10.88
17	11.49	11.56
18	11.86	12.04
19	11.93	12.27
20	12	12.48
21	12.09	12.68
22	12.12	12.89
23	12.2	13.08
24	12.24	13.28
25	12.33	13.48

- Expt and NGSPICE agreeing reasonably well.

Zener Regulator – Experiment and NGSPICE Simulations

- What could be done to have better agreement between Experiment and NGSPICE simulations?

Part C – DC Power Supply with a BJT Series Regulator



- Four parts:
  - Ref voltage (Zener)
  - Error Amp (BC547)
  - Series element for regulation (SL100)
  - Resistive network (R_1, R_2 and Pot)
- IC regulators are similar, but the above blocks, esp the first three very elaborate and rugged

BJT Series Regulator – Comparison between Experiment and NGSPICE Simulations

BJT Series Regulator, RL=1k		
	Expt	NGSPICE
Vin	Vout	Vout
15	11.66	11.37
16	11.74	11.54
17	11.8	11.71
18	11.87	11.88
19	11.95	12.04
20	12	12.20
21	12.09	12.37
22	12.14	12.54
23	12.2	12.70
24	12.26	12.86
25	12.31	13.03
(R1+R2)=25k		

- Expt and NGSPICE agreeing very well, better than the agreement we had for Zener regulator.

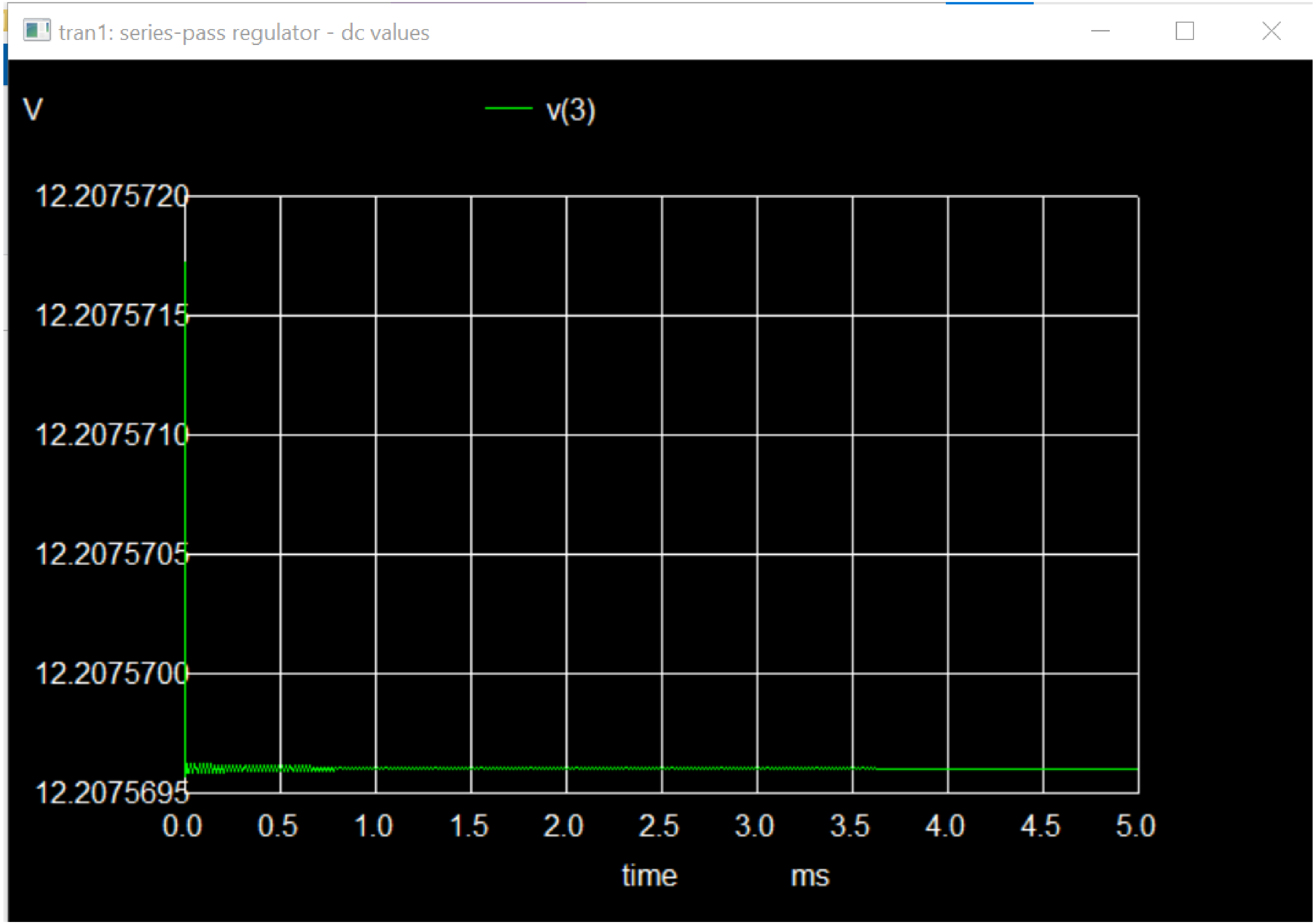
Comparison – Zener Regulator vs BJT Series Regulator

Zener Regulator		
RS=470		**Offset=10.8V**
RL=1k		**rz=125ohms**
	Expt	**NGSPICE**
Vin	Vout	Vout
15	10.14	10.20
16	10.87	10.88
17	11.49	11.56
18	11.86	12.04
19	11.93	12.27
20	12	12.48
21	12.09	12.68
22	12.12	12.89
23	12.2	13.08
24	12.24	13.28
25	12.33	13.48

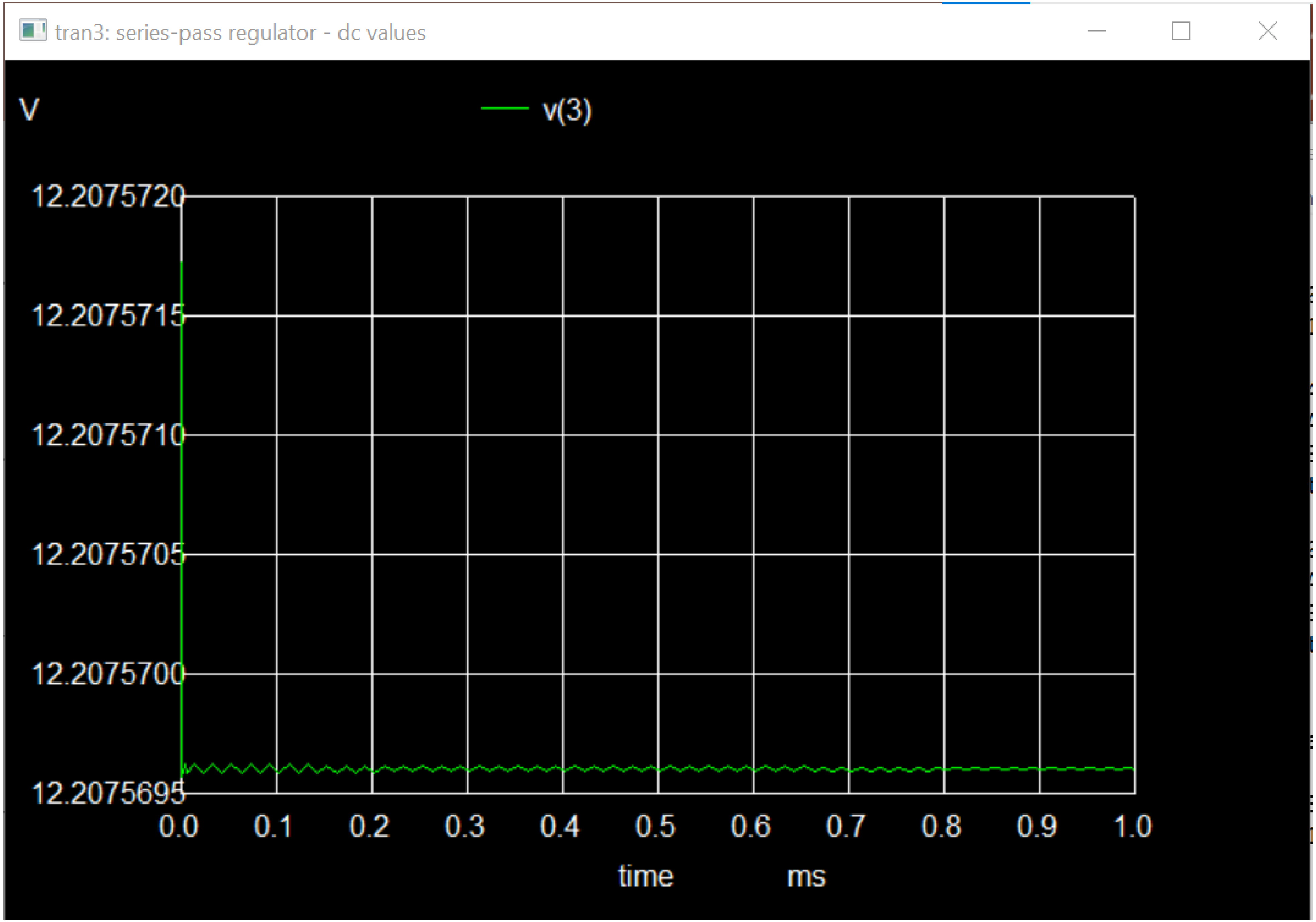
BJT Series Regulator, RL=1k		
	Expt	**NGSPICE**
Vin	**Vout**	**Vout**
15	11.66	11.37
16	11.74	11.54
17	11.8	11.71
18	11.87	11.88
19	11.95	12.04
20	12	12.20
21	12.09	12.37
22	12.14	12.54
23	12.2	12.70
24	12.26	12.86
25	12.31	13.03
(R1+R2)=25k		

- Zener Regulator:
  - ΔVout/Δvin = 2.19/10 = 0.219, or 20%
- BJT Ser Regulator
  - ΔVout/Δvin = 0.65/10 = 0.065, or 6.5%
- Commercial IC Voltage Regulators
  - ΔVout/Δvin = 0.1% typ.

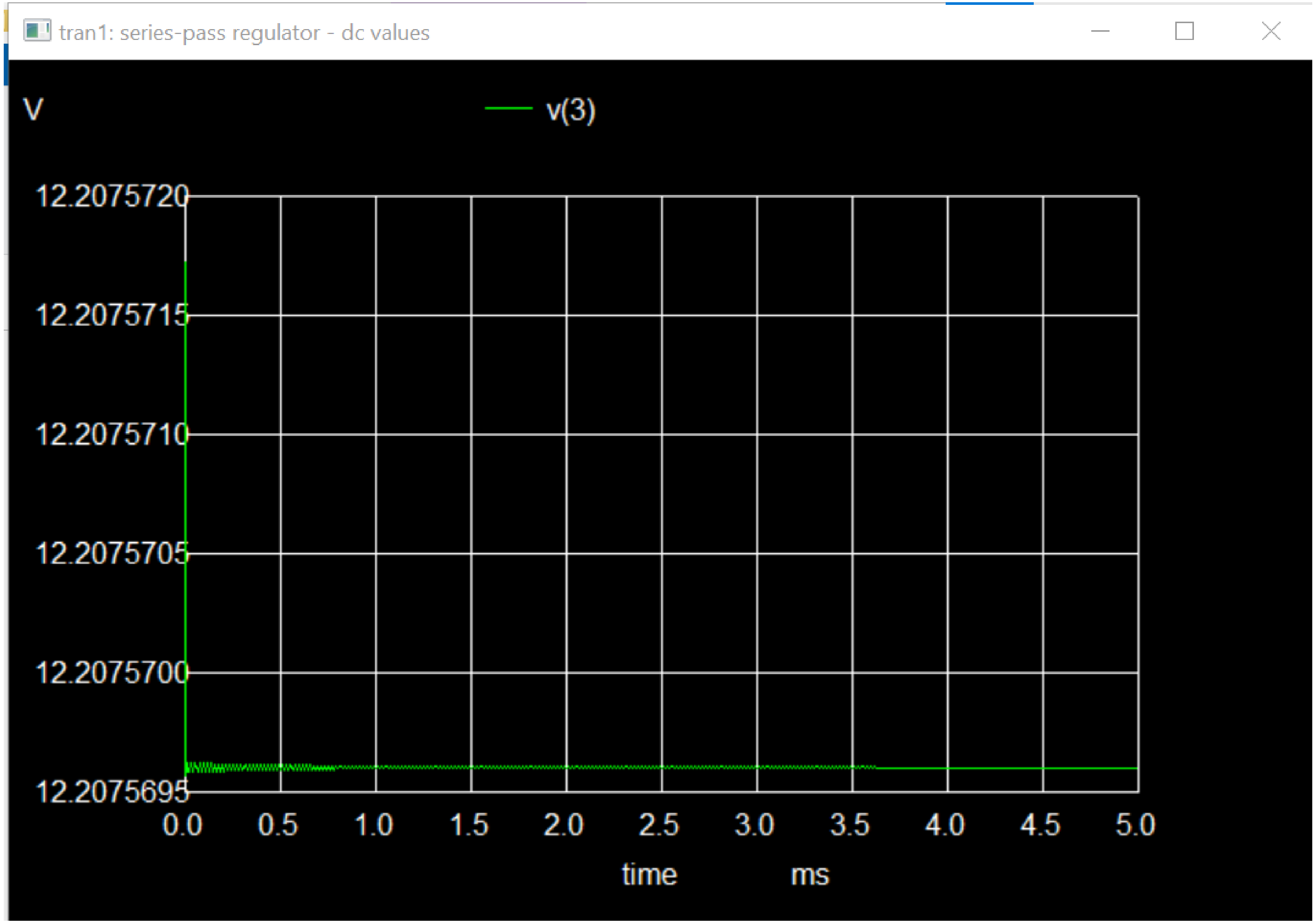
An interesting observation



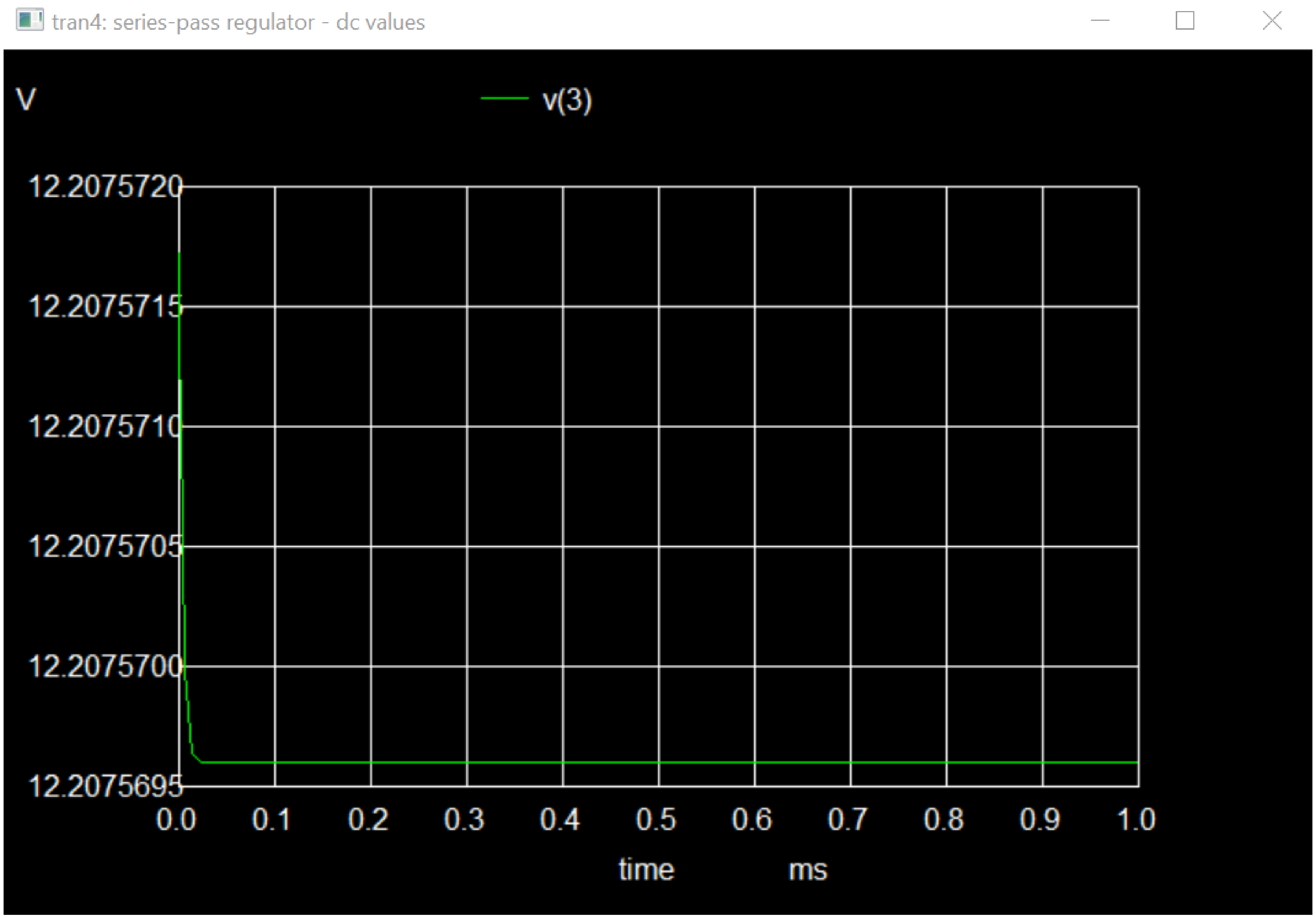
- .tran analysis
- Any problem?



- .tran analysis
- Any problem?



- .tran analysis
- Observation
  - Oscillations at V_{out}
  - Stabilizes after sometime
  - Stability problem
- Solution?



- Plot of Vout after putting a 1 μF capacitor (across R_L)
- Observation
    - Vout stable
- How to choose the Capacitor value?
    - Should be small value such as 1 μF, to have faster response

IC Voltage Regulators

- All IC regulators recommend a 1 µF (typ) capacitor (across R_L)
- Should not put too high a value.

Major Lessons from Expt 2 on DC Power Supply?

- Unregulated Power Supply (with a Capacitor filter)

- Zener Regulator

- BJT Series Regulator

Major Lessons from Expt 2: DC Power Supply

- Unregulated Power Supply (with a Capacitor filter)
  - Choose C carefully; a small value would do (typically 220 to 470μF)
  - Do not increase C in order to reduce the ripple voltage
- Zener Regulator
  - A good option if load currents are, say up to about 10 mA
  - Not a good choice for large Vin and RL ranges
- BJT Series Regulator
  - A good circuit to illustrate the operation of an IC regulator
  - Reasonably good regulation