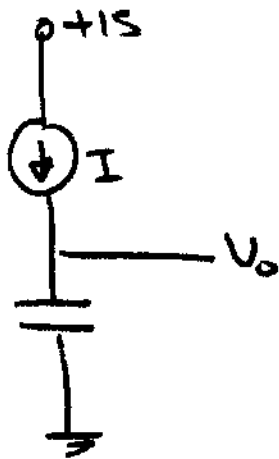


Ramp Generator Design

- First choose a capacitor and a current source



$$\frac{dV_o}{dt} = \frac{I}{C}$$

- we want a 0-5V 20KHz Ramp



$$\frac{dV}{dt} = \frac{5V}{50\mu s} = 10^5 V/s = 10 V/\mu s$$

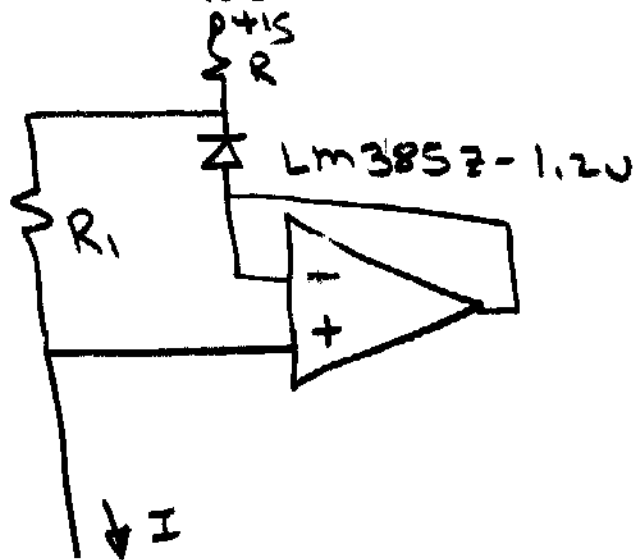
(2)

So we want $\frac{I}{C} = 10 \text{ V}/\mu\text{s}$

Choose $I = 1 \mu\text{A} \Rightarrow C = 10 \text{ pF} \Rightarrow \text{Too small}$

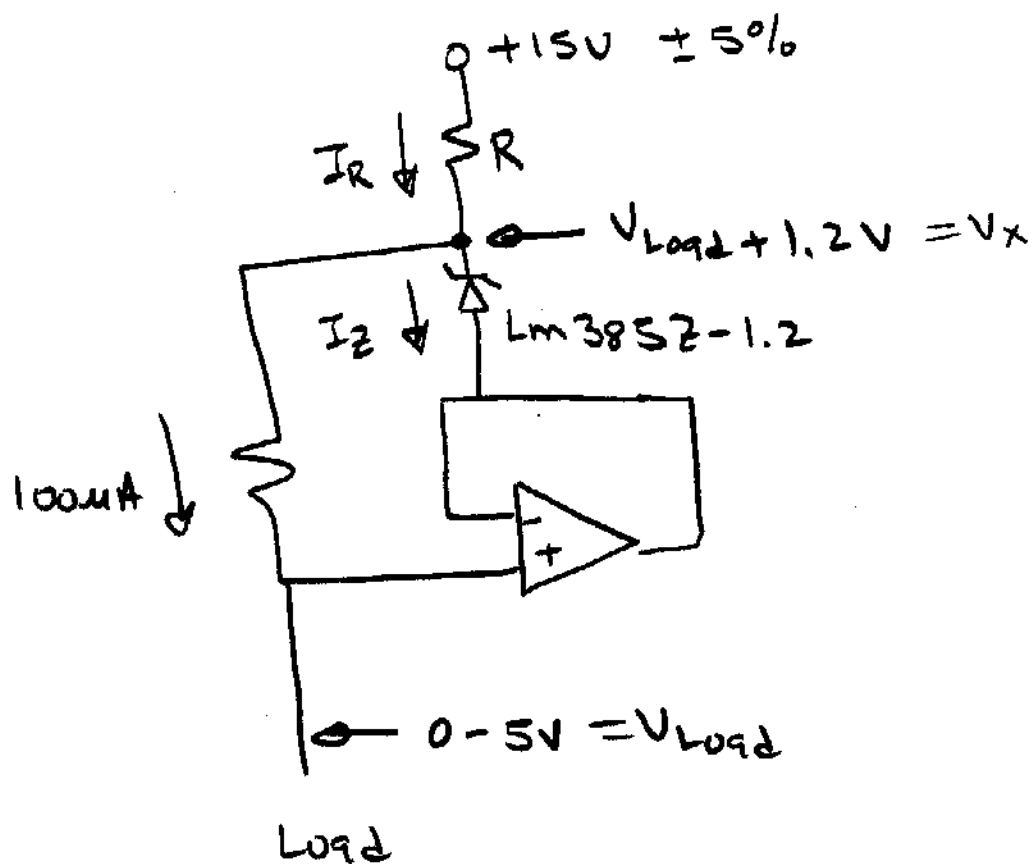
choose $C = 1 \text{ nF}$, then $I = 100 \mu\text{A}$

So, Design a $100 \mu\text{A}$ Current Source. Use
The one below



$$R_1 = \frac{1.2 \text{ V}}{100 \mu\text{A}} = 12 \text{ k}\Omega, 1\%$$

- Next, Find R . R must be chosen to ③
Limit the current through the LM385Z-1.2



$$I_R = \frac{V_{CC} - V_x}{R}$$

$$I_{Rmax} = \frac{V_{CC} - V_{xmin}}{R} = \frac{15V - 1.2V}{R}$$

$$I_{Zmax} = I_{Rmax} - I_{Load} = \frac{15V - 1.2V}{R} - 100\mu A$$

(4)

- From the data sheet $10\mu A \leq I_Z \leq 20\mu A$

So $I_{Zmax} < 20\mu A$

OR $\frac{15V - 1.2V}{R} - 100\mu A < 20\mu A$

OR $R \geq 686\Omega$

Now Look at the min condition

$$I_{Rmin} = \frac{V_{CCmin} - V_{xmax}}{R} = \frac{14.25V - (5.5V + 1.2V)}{R}$$

$$I_{Zmin} = I_{Rmin} - I_{Load} = \frac{7.49V}{R} - 100\mu A$$

From Data Sheet $I_{Zmin} \geq 10\mu A$ so

$$\frac{7.49V}{R} - 100\mu A > 10\mu A$$

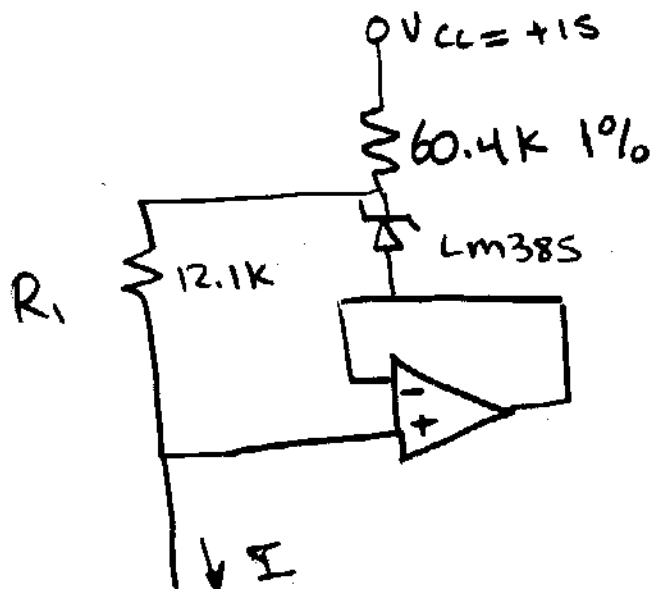
$$\Rightarrow R \leq 68.09k$$

my guess of what
max ramp voltage will be
max voltage of
LM385

⑤

so we need $686\Omega \leq R \leq 68.09K$

choose $R = 60.4K$ 1% to limit power dissipation and allow a little extra tolerance

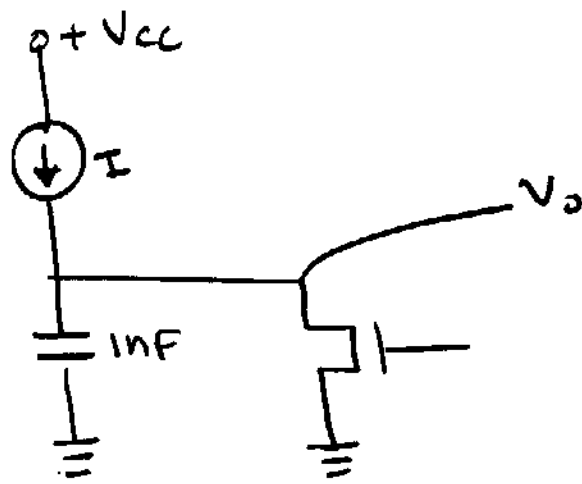


WORST case calculations

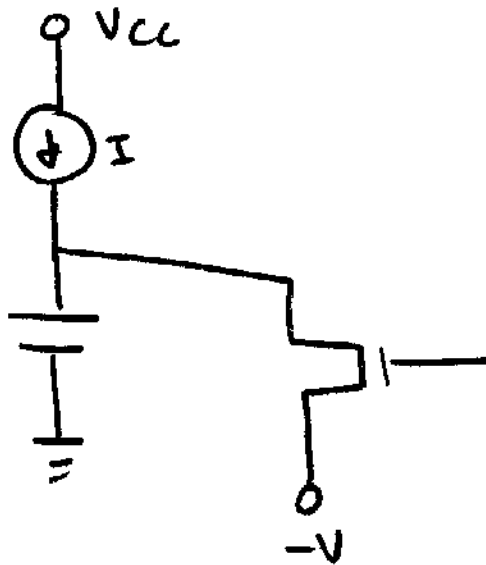
$$I_{max} = \frac{V_{zmax}}{R_{min}} = \frac{1.26V}{11.979K} = 105.2\mu A$$

$$I_{min} = \frac{V_{zmin}}{R_{max}} = \frac{1.205V}{12.221K} = 98.6\mu A$$

6



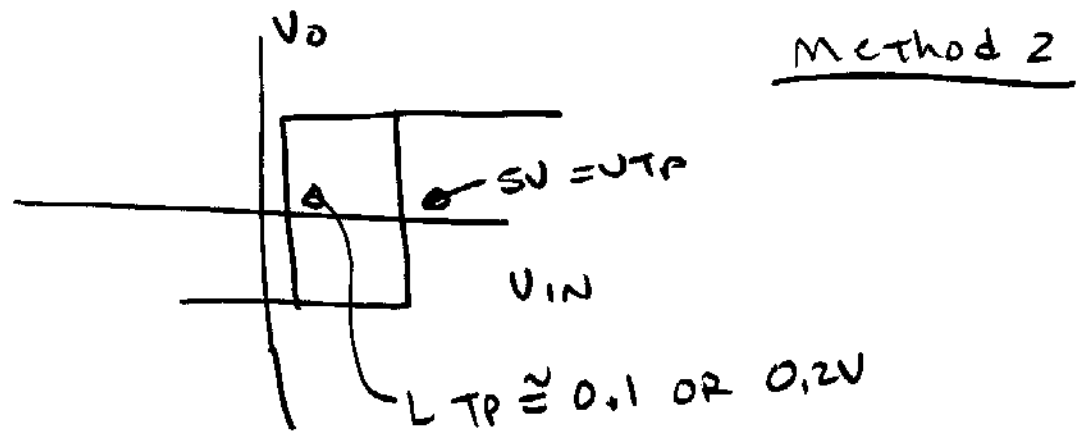
Note: The Switch can never discharge the Cap all the way to zero. To make our circuit work, we can do one of the following



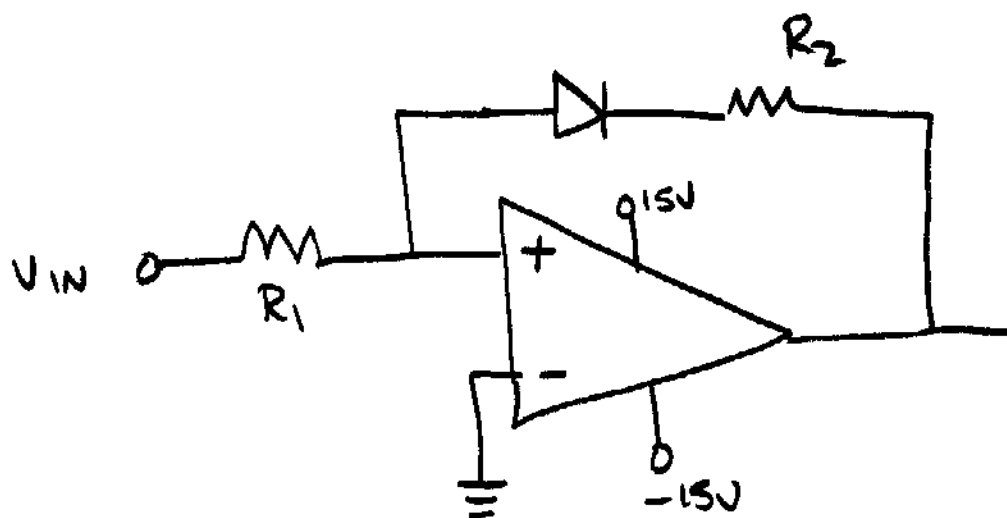
Method 1

← Discharge the Cap to a Negative Voltage

OR Design a Schmitt Trigger with an LTP a bit higher than 0V



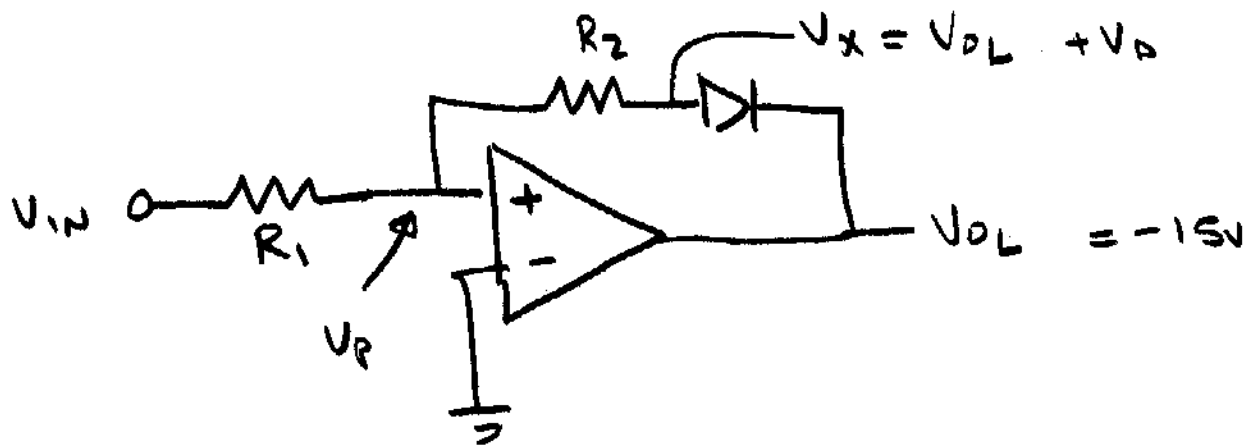
- Hmm. a Schmitt Trigger with a LTP of Zero is easy to design. Use method 1.



$LTP = 0$

(8)

UTP : $V_O = -15\text{ V}$, Diode on



$$V_P = \frac{V_x R_1}{R_1 + R_2} + \frac{V_{IN} R_2}{R_1 + R_2}$$

UTP occurs when $V_P = 0$. Find V_{IN} when

$$V_P = 0$$

$$\frac{V_x R_1}{R_1 + R_2} + \frac{V_{IN} R_2}{R_1 + R_2} = 0$$

$$V_{IN} = U_{TP} = -\frac{V_x R_1}{R_2}$$

⑨

- Solve for a Typical Value of $U_{TP} = 5V$.

$$U_{TP} = \frac{-V_x R_1}{R_2} = -\frac{(V_{OL} + V_D) R_1}{R_2} = -\frac{(-15V + 0.7) R_1}{R_2}$$

$$= 5V$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{5V}{14.3V} = 0.34965$$

Choose $R_2 = 10K \ 1\%$ Then $R_1 = 3.4965K$

Choose $R_1 = 3.48K \ 1\%$

Tolerance calculations

L_{TP} - No Tolerance if we don't include bias currents & offset voltages

$$U_{TP} = \frac{-(V_{OL} + V_D) R_1}{R_2} ; \text{ Assume } 0.4V \leq V_D \leq 0.5V$$

$$U_{TPmax} = \frac{-(V_{OLmax} + V_{Dmin}) R_{1max}}{R_{2min}}$$

$V_{CCmax} = 15.75V$

$$= \frac{-(-15.75 - 0.4V) 3.5148K}{9.9K} = 5.45V$$

$$U_{TPmin} = \frac{-(V_{OLmin} + V_{Dmax}) R_{1min}}{R_{2max}}$$

$$= \frac{-(-V_{CCmin} - 1.5V + V_{Dmin}) R_{1min}}{R_{2max}}$$

$$= \frac{-(-14.25 + 1.5V + 1V) 3.4452K}{10.1K}$$

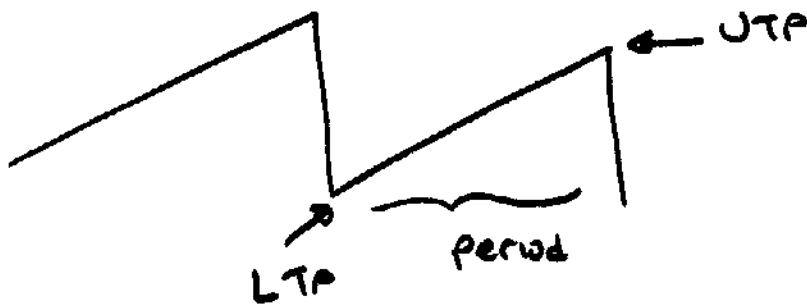
$$= 4.008V$$

$$\frac{dV}{dt} = \frac{I}{C}$$

$$\left. \frac{dV}{dt} \right|_{\max} = \frac{I_{\max}}{C_{\min}} = \frac{105.2 \mu A}{0.98 nF} = 10.735 V/\mu s$$

Use a 2% capacitor

$$\left. \frac{dV}{dt} \right|_{\min} = \frac{I_{\min}}{C_{\max}} = \frac{98.6 \mu A}{1.02 nF} = 9.66 V/\mu s$$



$$\text{Max period} = \frac{U_{TP\max} - L_{TP\min}}{\left(\frac{dV}{dt} \right)_{\min}} = \frac{5.45V - 0V}{9.66 V/\mu s} =$$

$$= 56.4 \mu s$$

$$\text{min Freq} = 17.73 \text{ kHz}$$

$$\text{min period} = \frac{UTP_{\min} - LTP_{\max}}{(dV/dt)_{\max}} = \frac{4.008V - 0V}{10.735V/\mu s}$$

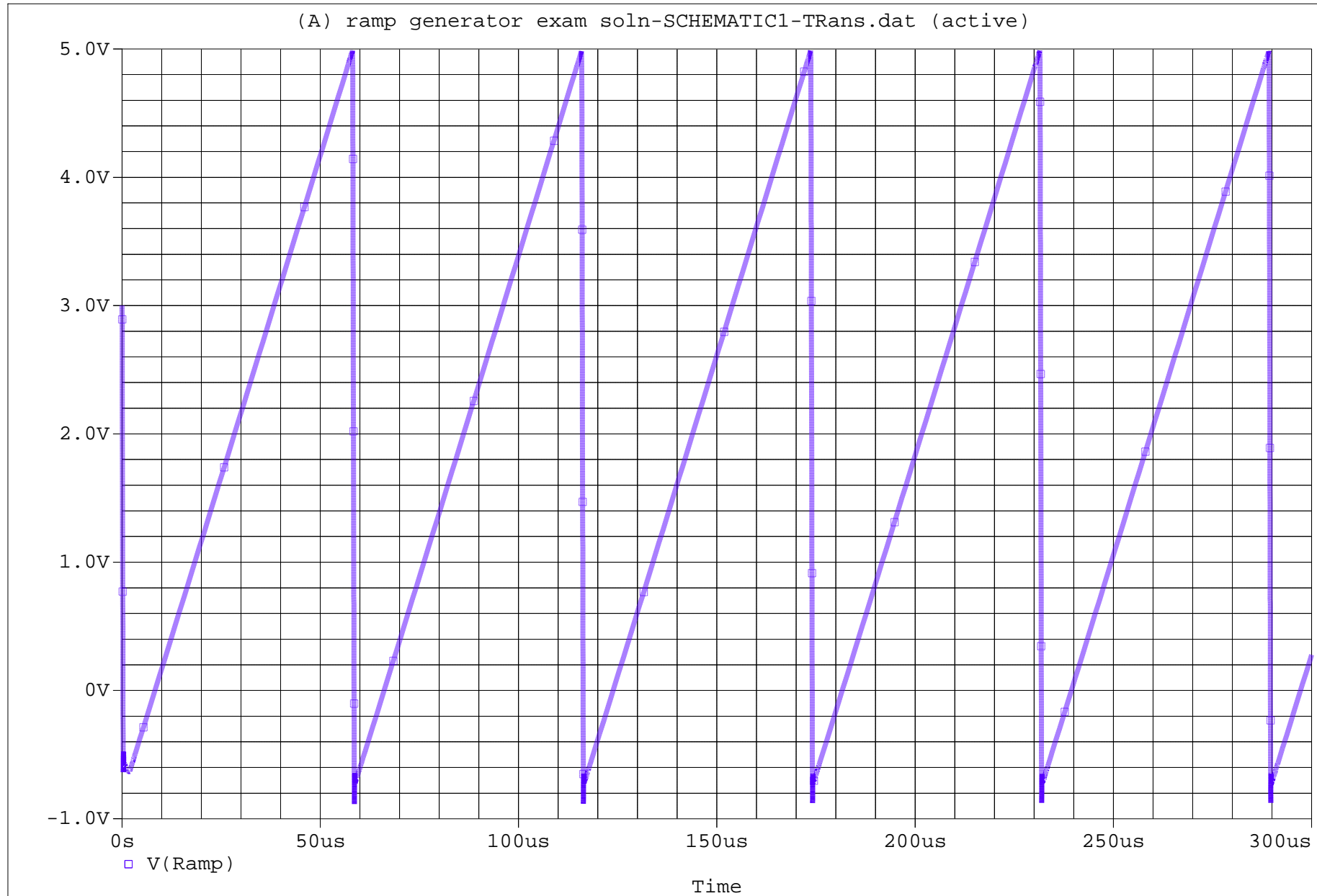
$$= 37.34\mu s$$

$$\text{max frequency} = 26\text{ kHz}$$

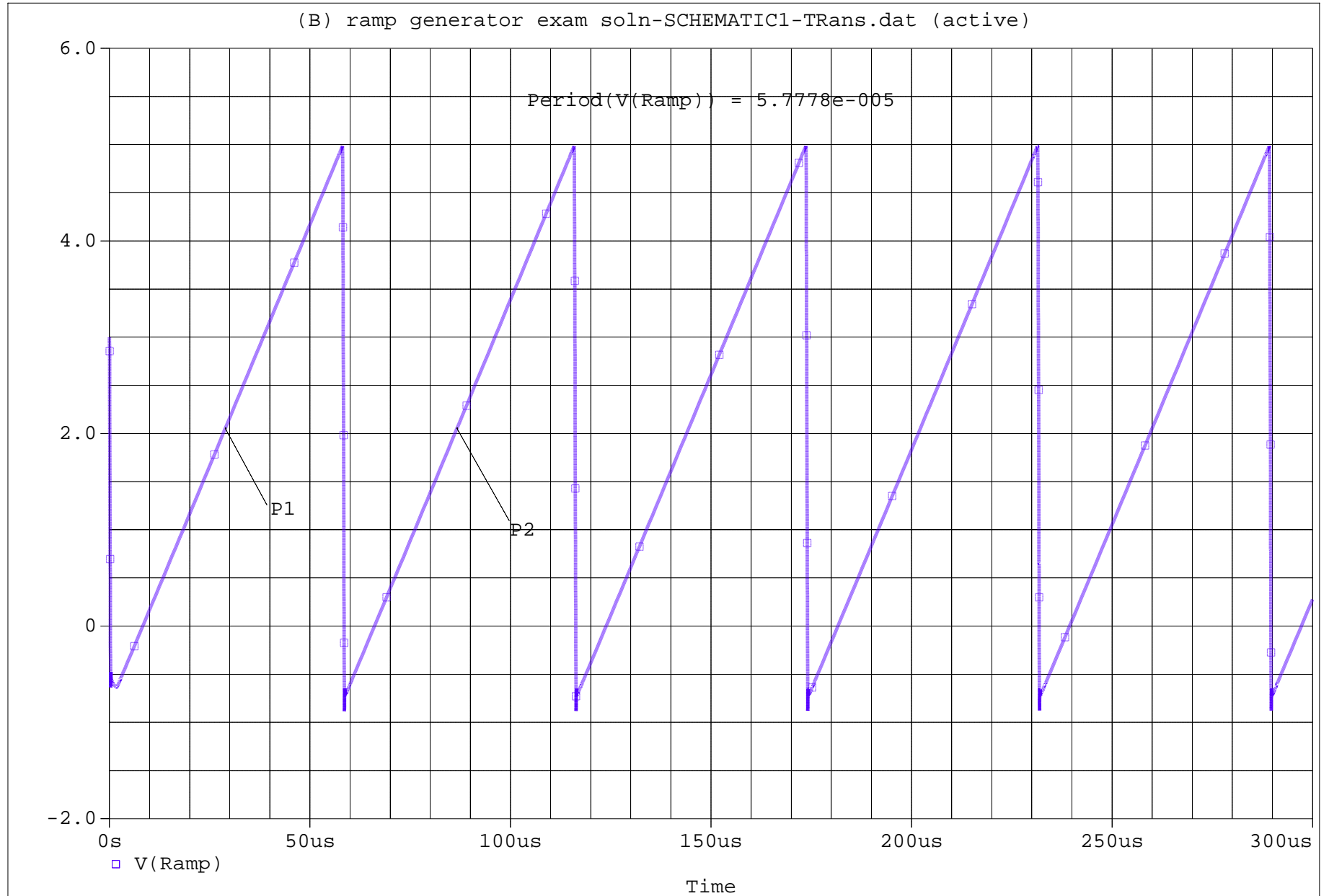
- Solutions don't include the ramp fall time, or opamp sat time

| | Calculated | Pspice | worst min | case max |
|-----------|------------|----------------|---------------|--------------|
| Period | 50 μs | 57.778 μs | 37.34 μs | 56.4 μs |
| Frequency | 20kHz | 17.3kHz | 17.73k | 26kHz |
| Ramp Peak | 5V | 4.9857 | 4.008 | 5.45V |
| Ramp min | 0 | -0.875 | 0 | 0 |

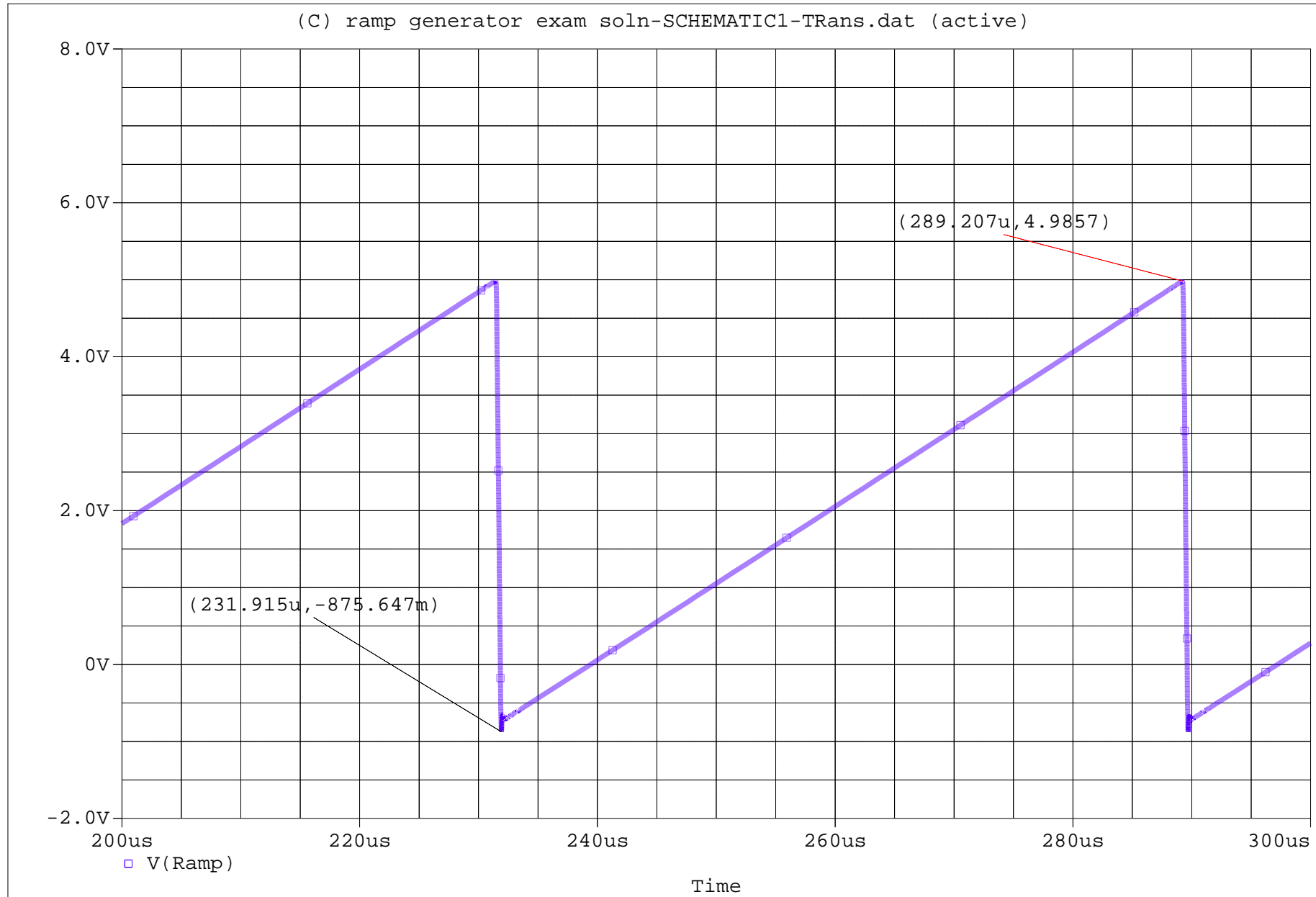
** Profile: "SCHEMATIC1-TRans" [C:\Website\Rose_Classes\ECE497\Exams\Fall 2002\ramp generator exa...
Date/Time run: 11/21/02 10:13:16 Temperature: 27.0



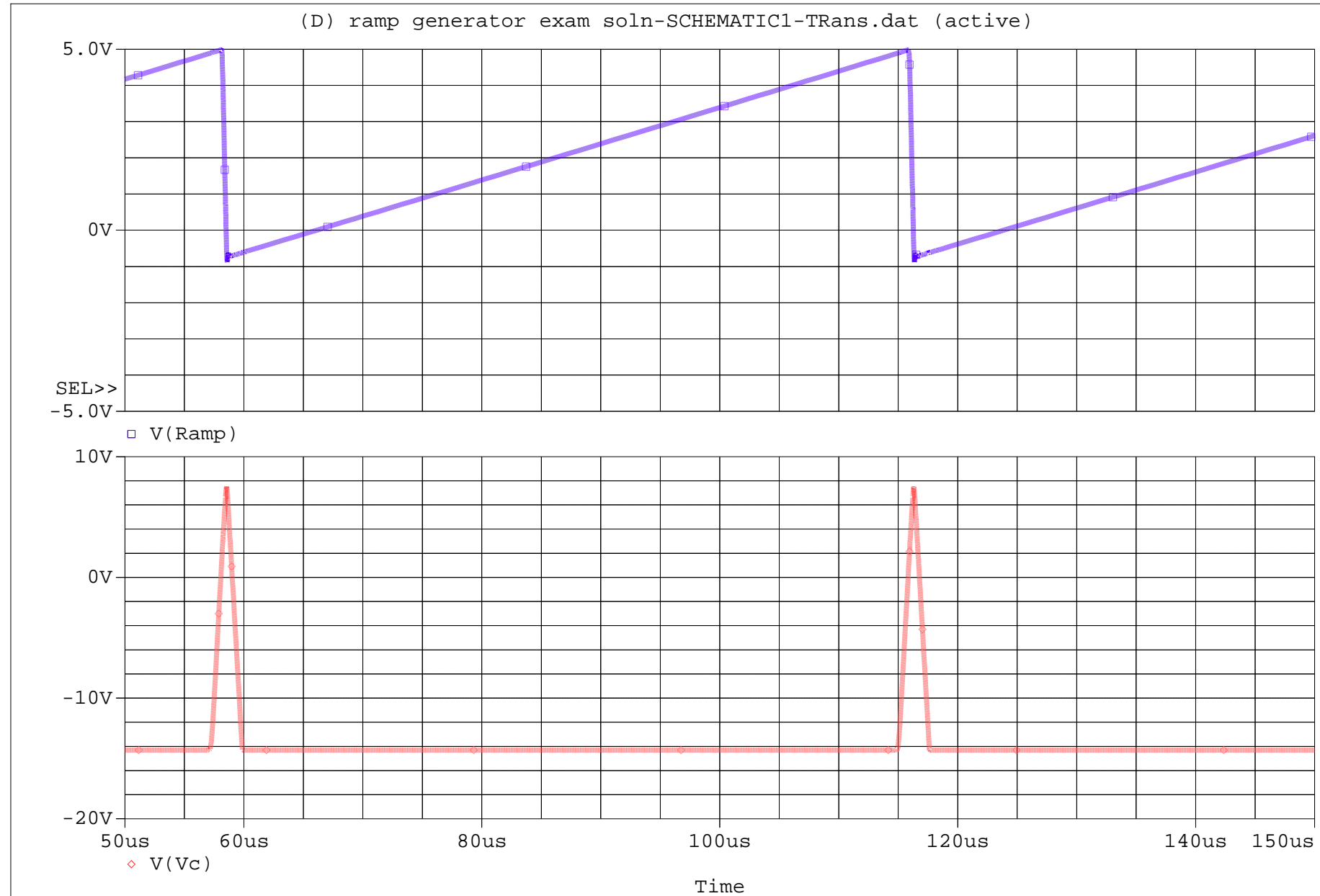
** Profile: "SCHEMATIC1-TRans" [C:\Website\Rose_Classes\ECE497\Exams\Fall 2002\ramp generator exa...
Date/Time run: 11/21/02 10:13:16 Temperature: 27.0



** Profile: "SCHEMATIC1-TRans" [C:\Website\Rose_Classes\ECE497\Exams\Fall 2002\ramp generator exa...
Date/Time run: 11/21/02 10:13:16 Temperature: 27.0



** Profile: "SCHEMATIC1-TRans" [C:\Website\Rose_Classes\ECE497\Exams\Fall 2002\ramp generator exa...
Date/Time run: 11/21/02 10:13:16 Temperature: 27.0



LM185-1.2/LM285-1.2/LM385-1.2

Micropower Voltage Reference Diode

General Description

The LM185-1.2/LM285-1.2/LM385-1.2 are micropower 2-terminal band-gap voltage regulator diodes. Operating over a 10 μ A to 20 mA current range, they feature exceptionally low dynamic impedance and good temperature stability. On-chip trimming is used to provide tight voltage tolerance. Since the LM185-1.2 band-gap reference uses only transistors and resistors, low noise and good long term stability result.

Careful design of the LM185-1.2 has made the device exceptionally tolerant of capacitive loading, making it easy to use in almost any reference application. The wide dynamic operating range allows its use with widely varying supplies with excellent regulation.

The extremely low power drain of the LM185-1.2 makes it useful for micropower circuitry. This voltage reference can be used to make portable meters, regulators or general purpose analog circuitry with battery life approaching shelf life.

Further, the wide operating current allows it to replace older references with a tighter tolerance part.

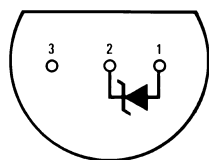
The LM185-1.2 is rated for operation over a -55°C to 125°C temperature range while the LM285-1.2 is rated -40°C to 85°C and the LM385-1.2 0°C to 70°C . The LM185-1.2/LM285-1.2 are available in a hermetic TO-46 package and the LM285-1.2/LM385-1.2 are also available in a low-cost TO-92 molded package, as well as SO and SOT-23. The LM185-1.2 is also available in a hermetic leadless chip carrier package.

Features

- ± 4 mV ($\pm 0.3\%$) max. initial tolerance (A grade)
- Operating current of 10 μ A to 20 mA
- 0.6 Ω max dynamic impedance (A grade)
- Low temperature coefficient
- Low voltage reference — 1.235V
- 2.5V device and adjustable device also available
- LM185-2.5 series and LM185 series, respectively

Connection Diagrams

T0-92
Plastic Package (Z)

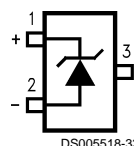


DS005518-10

Bottom View

Order Number LM285Z-1.2,
LM285BXZ-1.2, LM285BYZ-1.2
LM385Z-1.2, LM385BZ-1.2
LM385BXZ-1.2 or LM385BYZ-1.2
See NS Package Number Z03A

SOT23



DS005518-33

* Pin 3 is attached to the Die Attach Pad (DAP) and should be connected to Pin 2 or left floating.

Order Number LM385M3-1.2
See NS Package Number MA03B

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

(Note 2)

| | |
|--------------------------------------|-----------------|
| Reverse Current | 30 mA |
| Forward Current | 10 mA |
| Operating Temperature Range (Note 3) | |
| LM185-1.2 | -55°C to +125°C |
| LM285-1.2 | -40°C to +85°C |
| LM385-1.2 | 0°C to 70°C |

Storage Temperature -55°C to +150°C

Soldering Information

TO-92 package: 10 sec. 260°C

TO-46 package: 10 sec. 300°C

SO and SOT Pkg.

Vapor phase (60 sec.) 215°C

Infrared (15 sec.) 220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Note 4)

| Parameter | Conditions | Typ | LM185-1.2 LM185BX-1.2 LM185BY-1.2 LM285-1.2 LM285BX-1.2 LM285BY-1.2 | | LM385B-1.2 LM385BX-1.2 LM385BY-1.2 | | LM385-1.2 | | Units (Limit) |
|-----------------------------------------------|------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------|-----------------------------|------------------------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------------|
| | | | Tested Limit (Notes 5, 8) | Design Limit (Note 6) | Tested Limit (Note 5) | Design Limit (Note 6) | Tested Limit (Note 5) | Design Limit (Note 6) | |
| Reverse Breakdown Voltage | $T_A = 25^\circ\text{C}$, $10\ \mu\text{A} \leq I_R \leq 20\ \text{mA}$ | 1.235 | 1.223 1.247 | | 1.223 1.247 | | 1.205 1.260 | | V(Min) V(Max) |
| Minimum Operating Current | $T_A = 25^\circ\text{C}$ | 8 | 10 | 20 | 15 | 20 | 15 | 20 | μA |
| | LM385M3-1.2 | | | | | | 10 | 15 | (Max) |
| Reverse Breakdown Voltage Change with Current | $10\ \mu\text{A} \leq I_R \leq 1\ \text{mA}$ | | 1 | 1.5 | 1 | 1.5 | 1 | 1.5 | mV |
| | $1\ \text{mA} \leq I_R \leq 20\ \text{mA}$ | | 10 | 20 | 20 | 25 | 20 | 25 | mV (Max) |
| Reverse Dynamic Impedance | $I_R = 100\ \mu\text{A}$, $f = 20\ \text{Hz}$ | 1 | | | | | | | Ω |
| Wideband Noise (rms) | $I_R = 100\ \mu\text{A}$, $10\ \text{Hz} \leq f \leq 10\ \text{kHz}$ | 60 | | | | | | | μV |
| Long Term Stability | $I_R = 100\ \mu\text{A}$, $T = 1000\ \text{Hr}$, $T_A = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ | 20 | | | | | | | ppm |
| Average Temperature Coefficient (Note 7) | $I_R = 100\ \mu\text{A}$ X Suffix Y Suffix All Others | | 30 50 | 150 | 30 50 | 150 | | 150 | ppm/°C ppm/°C ppm/°C (Max) |

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

Note 2: Refer to RETS185H-1.2 for military specifications.

Note 3: For elevated temperature operation, T_j max is:

| | |
|-------|-------|
| LM185 | 150°C |
| LM285 | 125°C |
| LM385 | 100°C |

| Thermal Resistance | TO-92 | TO-46 | SO-8 | SOT23 |
|-------------------------------------|------------------------------------------------|---------|---------|---------|
| θ_{JA} (junction to ambient) | 180°C/W (0.4" leads) 170°C/W (0.125" leads) | 440°C/W | 165°C/W | 283°C/W |
| θ_{JC} (junction to case) | N/A | 80°C/W | N/A | N/A |

Note 4: Parameters identified with boldface type apply at temperature extremes. All other numbers apply at $T_A = T_J = 25^\circ\text{C}$.