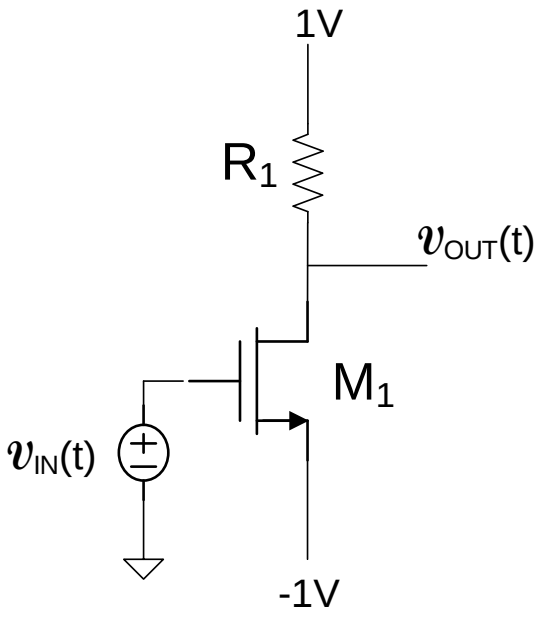
EE 330
Homework 11
Fall 2019 Due Friday Nov 8

All problems are weighted equally. Characteristics for an SCR and for a Triac are appended at the end of this assignment. Use these characteristics when solving the problems involving Thyristors. Unless specified to the contrary, assume all n-channel MOS transistors have model parameters $\mu_n C_{OX} = 350\mu A/V^2$,$V_{Tn} = 0.5V$, and $\lambda=0$, all p-channel transistors have model parameters $\mu_p C_{OX} = 70\mu A/V^2$,$V_{Tp}= -0.5V$, and $\lambda=0$, and all JFET devices are from a process with $I_{DSSn0}= 100\mu A$, $I_{DSSp0}= 30\mu A$,$V_{Pp}=1V$, $V_{Pn}=-1V$, and , $\lambda=0$.

Problem 1 Consider the following circuit where $R_1=20K$. Size the device so that the amplifier has a voltage gain of -8 and a quiescent output voltage of 0V.

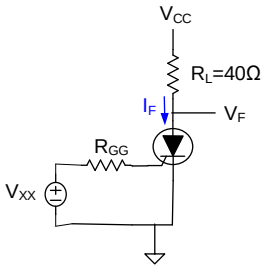


Problem 2 A circuit using an SCR that is rated at current levels of 10A is shown below. Relevant parameters from the datasheet for this device are appended at the end to this assignment. Assume the voltage V_{CC} is fixed at 50V and that the SCR is initially off.

a) If V_{XX} is increased to 12V to turn on the SCR, what is the maximum value of R_{GG} that can be used if the SCR must turn on for 0C<T<80C.

b) What will be the static power dissipation in the Anode when it is ON?

c) What will be the static power dissipation in the Gate if the gate signal V_{XX} remains at 12V and the value determined in part a) is used for R_{GG}?

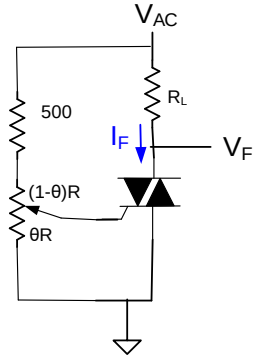


Problem 3 Assume the potentiometer in the following circuit has a full range value of R=500Ω, that R_L=20Ω and V_{AC}=60sin(2π60t). Assume the device is operating at a temperature of 25C and that it is characterized by the parameters given at the end of this assignment.

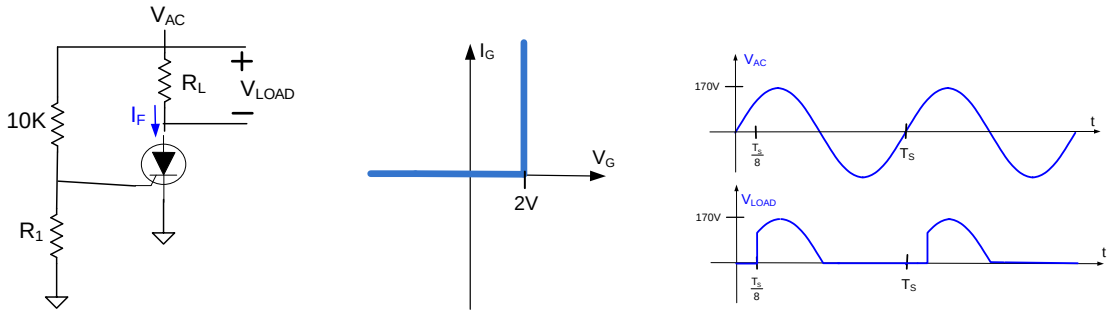
a) Determine $V_F(t)$ if θ=0.1

b) Determine the average power dissipation in the Triac for the value of θ given in part a)

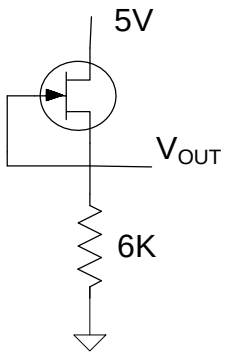
c) Which quadrant or quadrants are used to trigger the triac in this circuit?



Problem 4 Consider the following circuit. The waveforms V_{AC} is the 60Hz line voltage. Assume the SCR has a gate trigger voltage of 2Vand that the relationship between the gate current and the gate voltage of the SCR is as shown on the I_G:V_G plot on the right. Size the resistor R_1 so that the SCR turns on at T_S/8, T_S +T_S/8, 2T_S +T_S/8,…. as shown below for two periods of the V_{LOAD} waveform. The time T_S is the period of the 60 Hz AC line voltage.



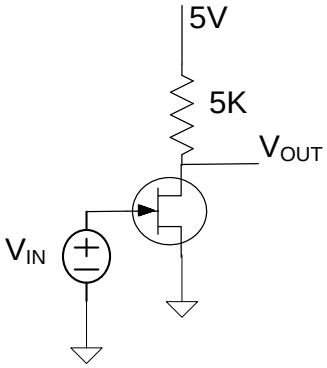
Problem 5 Assume the JFET in the following circuit has parameters I_{DSS}=100uA and V_P=-1V. Determine the output voltage.



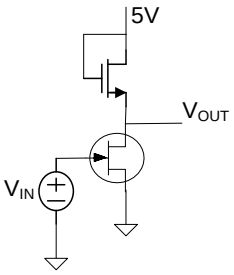
Problem 6 Assume the JFET in the following circuit has parameters I_{DSS}=100uA and V_P=-1V.

a) If the input voltage is a 1KH square wave that varies between +25mV and -25mV, obtain the output waveform

b) What is the maximum value of V_{IN} that can be applied to this circuit if the JFET is to operate normally (that is, the pn-junctions do not conduct significant current)



Problem 7 Assume the JFET in the following circuit has parameters I_{DSS}=100uA and V_P=-1V and the MOSFET is in a process that was characterized in the introduction to this HW assignment. If the length of the MOSFET is 8u, determine the width of the MOSFET so that the output voltage of the following circuit is 3V when V_{IN}=-0.5V.



Problem 8 Assume the drain current of a p-channel JFET is given by the expression

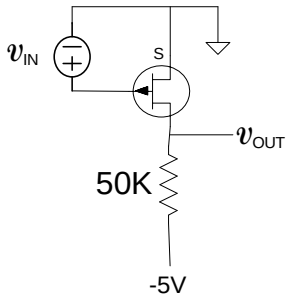
$$I_D = \begin{cases} 0 & V_{GS} > V_P \\ -\dfrac{2I_{DSSp0}W}{V_p^2 L}\left(V_{GS} - V_P - \dfrac{V_{DS}}{2}\right)V_{DS} & -0.3 < V_{GS} < V_P \quad V_{GS} + 0.3 > V_{DS} > V_{GS} - V_P \\ -\dfrac{I_{DSSp0}W}{L}\left(1 - \dfrac{V_{GS}}{V_P}\right)^2 (1 - \lambda V_{DS}) & -0.3 < V_{GS} < V_P \quad V_{DS} < V_{GS} - V_P \end{cases}$$

where the parameter I_{DDSp0} is related to the parameter I_{DDSp} that is often given in the model for a JFET by the expression

$$I_{DSSp} = \frac{W}{L} I_{DSSp0}$$

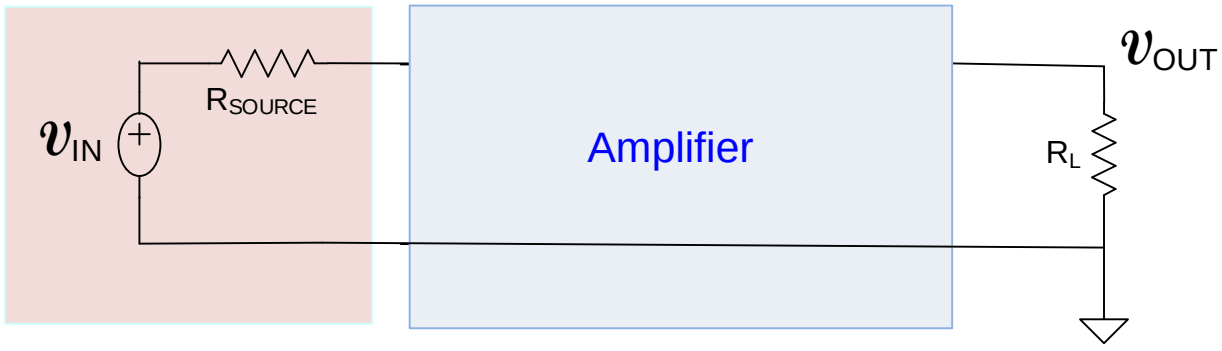
Develop a small-signal model of the JFET when operating in the saturation region.

Problem 9 Using the small-signal model of the JFET developed in the previous problem and the model parameters given at the top of this assignment, determine the operating point and small-signal voltage gain of the following circuit if W=10μm and L=15μm.



Problem 10 Consider an Amplifier characterizes by small-signal parameters $y_{11}=10^{-3}$ A/V y_{12}=-0.1 A/Vand $y_{22}=5x10^{-4}$A/V.

a) Determine the voltage gain if the amplifier is excited by a voltage source with a source impedance of 1KΩ and loaded with a 1KΩ resistive load.
b) Repeat part a) if the load impedance is increased to 100KΩ



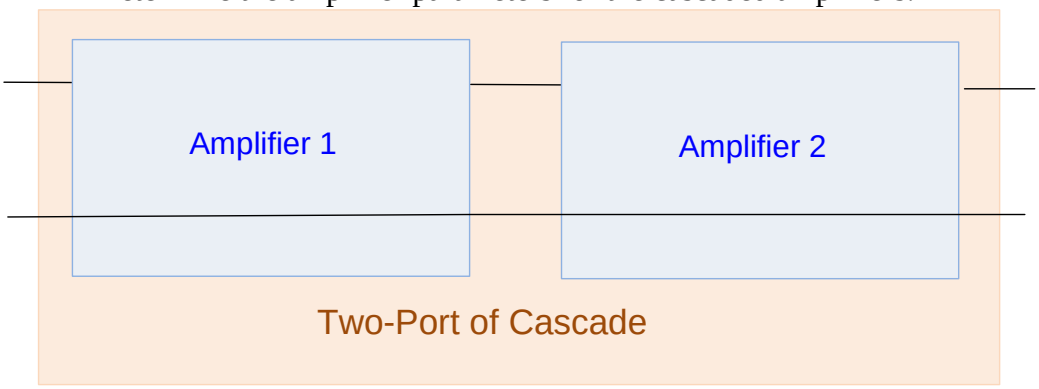
Problem 11 Consider a two-port amplifier with a common terminal between the input and the output characterized by the parameters $y_{11}=10^{-4}$ A/V y_{12}=-10 A/Vand y_{22}=0.1A/V.

a) Is this amplifier unilateral ?

b) Express the small signal two-port model of this amplifier in terms of the small-signal amplifier parameters R_{IN}, R_{OUT}, A_V, and A_{VR}.

c) If this amplifier is driven by a voltage source with 50Ω source impedance and loaded with a 1KΩ resistor, determine the voltage gain.

d) If two of these amplifiers are cascaded, they also form a two-port amplifier. Determine the amplifier parameters for the cascaded amplifiers.



Problem 12 Assume two amplifiers are cascaded. The first amplifier has small-signal amplifier parameters of A_{V1}=-10, R_{IN1}=10K and R_{o1}=1K. The second amplifier has small-signal amplifier parameters of A_{V2}=-20, R_{IN2}=5K, and R_{o2}=2K. Assume a capacitor coupled load of 1K is placed on the output and the input is driven by a voltage source with an output impedance of 500Ω. Determine the voltage gain from the input to the output.

Problem 13 Design a light dimmer circuit that will control a 100W $120V_{AC}$ incandescent lamp where the lamp is completely on when a dc control voltage is 5V, completely off when the dc control voltage is 0V, and that continuously varies in intensity from completely off to completely on as the control voltage is varied between 0V and 5V. You may assume Thyristors with the specifications given below are available for your design.

SCR Specifications:

I_{DRM} and I_{RRM} — Peak off-state current at V_{DRM} and V_{RRM}

I_{GT} — DC gate trigger current V_D = 6 V dc; R_L = 100 Ω

I_{GM} — Peak gate current

I_H — DC holding current; initial on-state current = 20 mA

I_T — Maximum on-state current

V_{DRM} and V_{RRM} — Repetitive peak off-state forward and reverse voltage

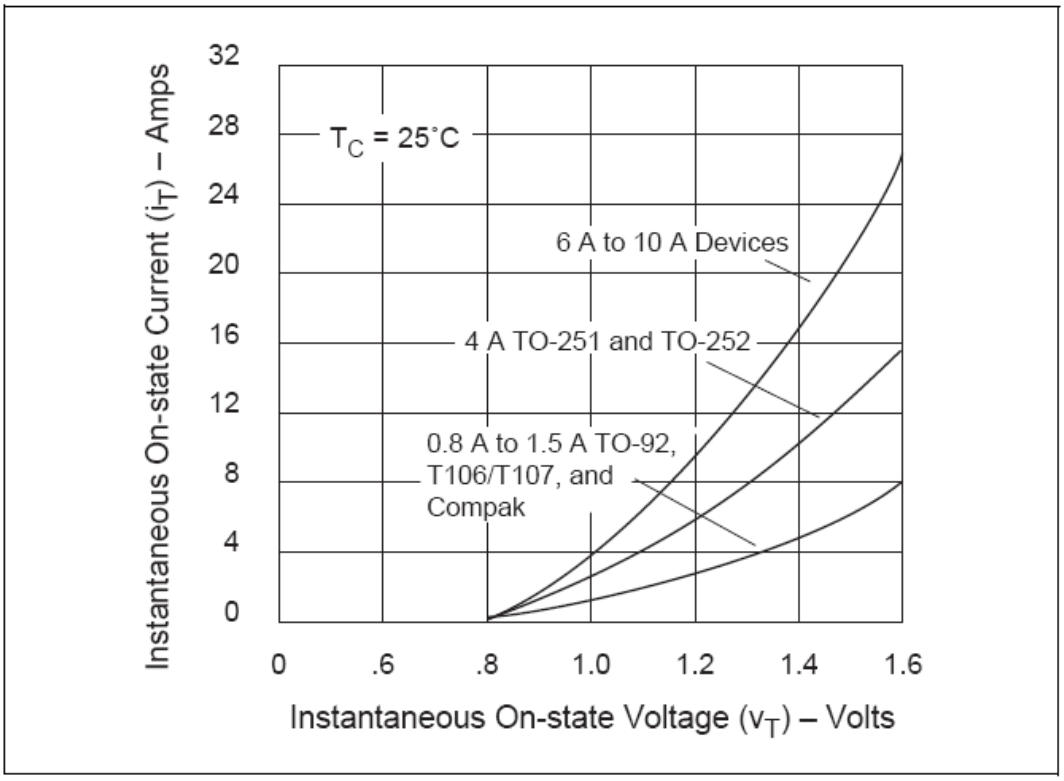
V_{GRM} — Peak reverse gate voltage

V_{GT} — DC gate trigger voltage; V_D = 6 V dc; R_L = 100 Ω

V_{TM} — Peak on-state voltage

I_T		V_{DRM} & V_{RRM}	I_{GT}	I_{DRM} & I_{RRM}		V_{TM}
Amps				μAmps		
$I_{T(RMS)}$	$I_{T(AV)}$	Volts	μAmps	T_C = 25 °C	T_C = 110 °C	Volts
MAX	MAX	MIN	MAX	MAX	MAX	MAX
10	**6.4**	**400**	**200**	**5**	**250**	**1.6**

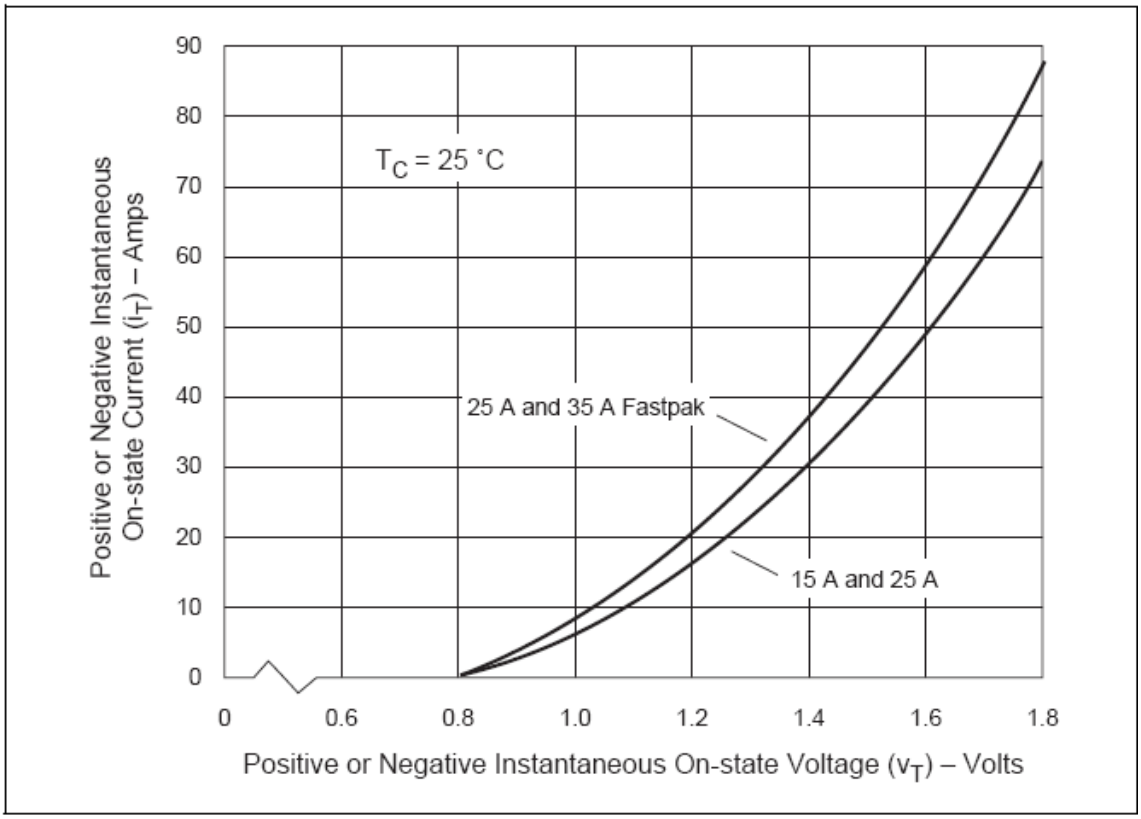
V_{GT}			I_H	I_{GM}	V_{GRM}	P_{GM}
Volts						
T_C = -40 °C	T_C = 25 °C	T_C = 110 °C	mAmps	Amps	Volts	Watts
MAX			MAX		MIN	
1	**0.8**	**0.25**	**6**	**1**	**6**	**1**

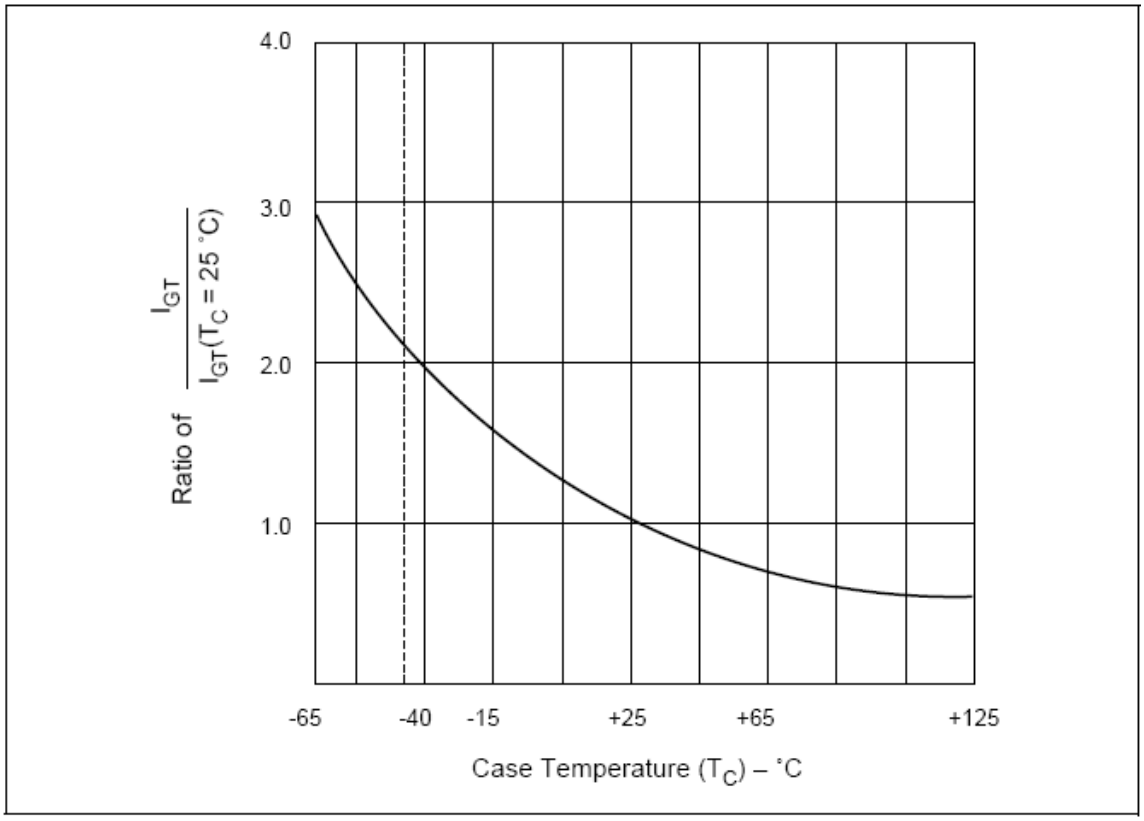

Instantaneous On-state Current (i_T) – Amps
32
28
24
20
16
12
8
4
0
T_C = 25°C
6 A to 10 A Devices
4 A TO-251 and TO-252
0.8 A to 1.5 A TO-92,
T106/T107, and
Compak
0
.6
.8
1.0
1.2
1.4
1.6
Instantaneous On-state Voltage (v_T) – Volts

TRIAC Specifications

V_{DRM}	I_{GT}					I_{DRM}		
	mAmps					mAmps		
Volts	QI	QII	QIII	QIV	QIV	T_C = 25 °C	T_C = 100 °C	T_C = 125 °C
MIN	MAX				TYP	MAX		
400	**50**	**50**	**50**			**0.05**	**0.5**	**2**

V_{TM}	V_{GT}	I_H	I_{GTM}	P_{GM}	$P_{G(AV)}$
Volts	Volts				
T_C = 25 °C	T_C = 25 °C	mAmps	Amps	Watts	Watts
1.6	**2.5**	**70**	**2**	**20**	**0.5**




4.0
3.0
2.0
1.0
Ratio of $\frac{I_{GT}}{I_{GT}(T_C = 25\ ^\circ C)}$
-65
-40
-15
+25
+65
+125
Case Temperature (T_C) – °C