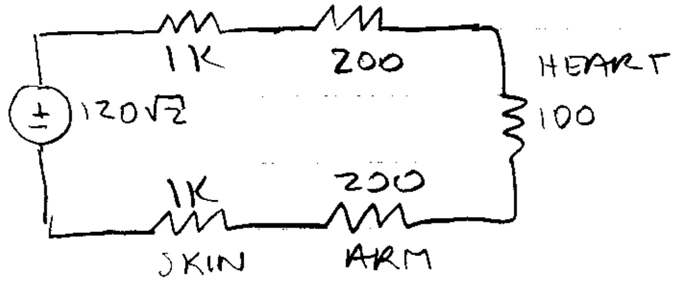
EE 5345
FALL '92
C. DAVILA

SOLUTIONS 14.1, 14.6, 14.9, 14.13, 14.17

14.1



$$I = \frac{120\sqrt{2}}{2K + 500} = 67 \text{ mA}$$, see also FIG. 14.1

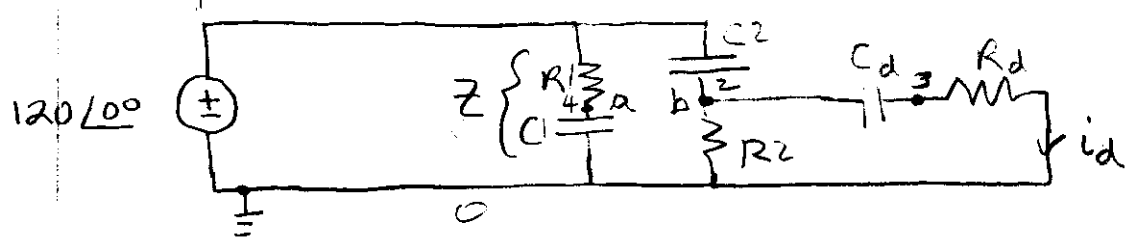
75 mA is typical.

assume a 10 x 10 cm C.S. area: $\frac{75 \text{ mA}}{100 \text{ cm}^2}$ = 0.75 mA/cm²

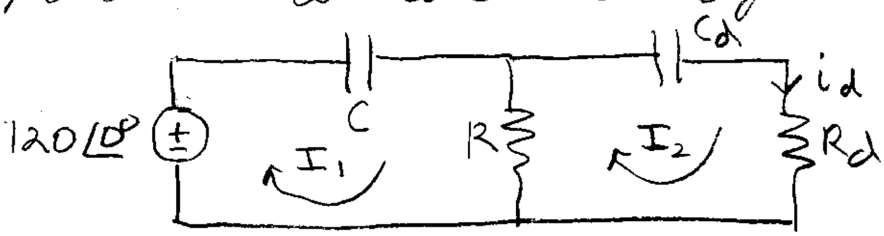
LOWEST THRESHOLD CURRENT DENSITY

$$1000\,\mu A / 100\ mm^2 \times \frac{1\ mA}{10^3\,\mu A} \times \frac{10^2\ mm^2}{1\ cm^2} = 1\ mA/cm^2$$ ≈ SAME

14.6 Monitor hazard current is the current (i_d) that flows through the detector when one of the isolated conductors in the I.T. is grounded*:



note Z doesnt affect id since it is parallel to the voltage source:



$$120 = \frac{1}{j\omega C} I_1 + R(I_1 - I_2)$$

$$120 = I_1\left(R + \frac{1}{j\omega C}\right) + I_2(-R) \quad (1)$$

* assuming no other devices plugged into IT.

$$0 = I_2\left(\frac{1}{j\omega C_d} + R_d\right) + R(I_2 - I_1)$$

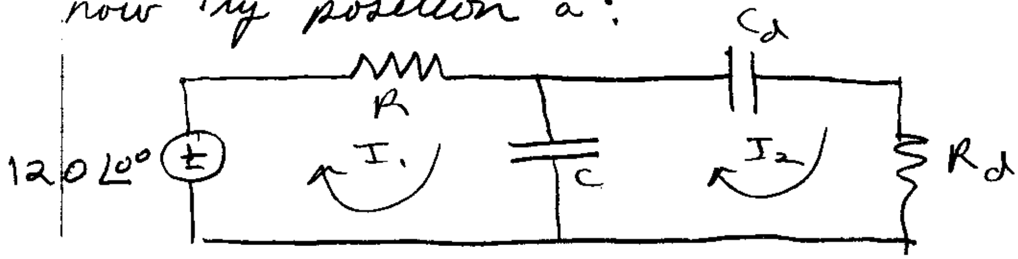
$$0 = +I_1(-R) + I_2(R + R_d + 1/j\omega C_d) \quad (2)$$

$$I_{ab} = \frac{\begin{vmatrix} R + 1/j\omega C & 120 \\ -R & 0 \end{vmatrix}}{\begin{vmatrix} R + 1/j\omega C & -R \\ -R & R + R_d + 1/j\omega C_d \end{vmatrix}}$$

$$= \frac{120R}{(R + 1/j\omega C)(R + R_d + 1/j\omega C_d) - R^2}$$

$$= \frac{120R}{\cancel{R^2} + \underline{RR_d} + \frac{R}{j\omega C_d} + \frac{R}{j\omega C} + \frac{R_d}{j\omega C} - \frac{1}{\omega^2 C C_d} - \cancel{R^2}} = \dot{i}_d \quad (3)$$

now try position a:



loop 1:

$$120 = I_1(R) + \frac{1}{j\omega C}(I_1 - I_2)$$

$$120 = \left(R + \frac{1}{j\omega C}\right)I_1 - \frac{1}{j\omega C}I_2$$

loop 2:

$$0 = \left(\frac{1}{j\omega C_d} + R_d\right)I_2 + \frac{1}{j\omega C}(I_2 - I_1)$$

$$0 = -\frac{1}{j\omega C}I_1 + \left(\frac{1}{j\omega C_d} + \frac{1}{j\omega C} + R_d\right)I_2$$

$$I_{2a} = \frac{\begin{vmatrix} R + \frac{1}{j\omega C} & 120 \\ -1/j\omega C & 0 \end{vmatrix}}{\begin{vmatrix} R + 1/j\omega C & -1/j\omega C \\ -1/j\omega C & \left(R_d + \frac{1}{j\omega C_d} + \frac{1}{j\omega C}\right) \end{vmatrix}}$$

$$= \frac{120/j\omega C}{\left(R + 1/j\omega C\right)\left(R_d + 1/j\omega C_d + 1/j\omega C\right) + 1/\omega^2 C^2}$$

$$= \frac{120/j\omega C}{RR_d + \frac{R}{j\omega C_d} + \frac{R}{j\omega C} + \frac{R_d}{j\omega C} - \frac{1}{\omega^2 C C_d}}$$

$$= \frac{120}{j\omega RR_d C + R\frac{C}{C_d} + R + R_d - j/\omega C_d}$$

$$= \frac{120\, C_d}{j\omega RR_d C C_d + RC + (R + R_d)C_d - j/\omega} = i_d \quad (4)$$

Lets try tweaking Rd in ③ + ④ until min (I_{2a}, I_{2b}) = 25 μA. This is hard to do analytically. It's easier to write a short computer program that evaluates I_{2a} + I_{2b} for different values of Rd:

```
clear;
% position b current

w=60*2*pi;
R=10000;
C=0.3E-6;
Cd=0.01E-6;

for jj=1:1000

%Rd=33000;
Rd=input('enter Rd: ');
Rd=Rd*1000000;

i2b=120*R/(Rd*(R+1/(i*w*C))+R/(i*w*Cd)+R/(i*w*C)-1/(w^2*C*Cd));
abs(i2b)


%position a current

i2a=120*Cd/(Cd*(R+Rd)+R*C+i*w*R*Rd*C*Cd-i/w);
abs(i2a)

end
```

$\underline{\underline{Rd = 3.165 M\Omega}}$ gives $|I_{2a}| = 24.989 \mu A$

$|I_{2b}| = 28.262 \mu A$

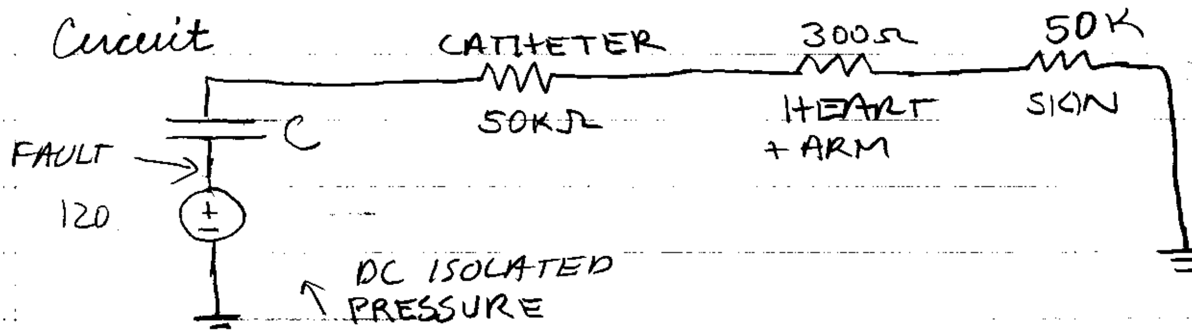
- you can also use SPICE.

Total hazard index: The total hazard index is defined as the total current, in milliamperes, that would flow to ground through a low-impedance fault if it were connected between either isolated conductor and ground. The total hazard index is made up of two components: the monitor hazard index and the fault hazard index. A LIM is usually set to alarm for a total hazard index of 2 mA.

Monitor hazard index: The monitor hazard index is the hazard current due to the LIM with no other devices plugged into the isolated power transformer.

Fault hazard index: The fault hazard index is the hazard current of a given isolated system with all devices connected except the LIM.

14.9 Circuit



DC ISOLATED PRESSURE SENSOR, C PROVIDES DC ISOLATION

$$I_{MAX} = 10\,\mu A = \frac{120}{\left|50K + 300 + 50K + \frac{1}{j\omega C}\right|}$$

$$\doteq \frac{120}{\left[(100.3K)^2 + \left(\frac{1}{2\pi \times 60C}\right)^2\right]^{1/2}}$$

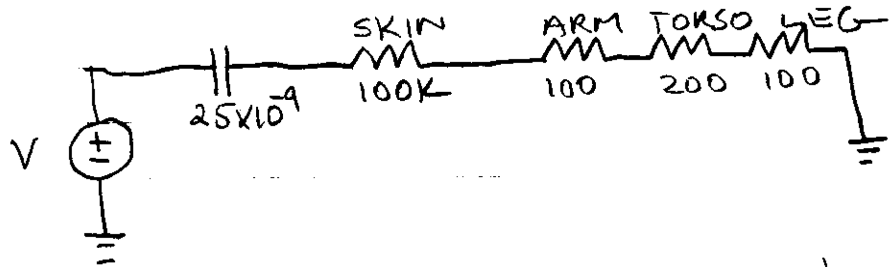
$$(100.3K)^2 + \left(\frac{1}{120\pi C}\right)^2 = \left(\frac{120}{10^{-5}}\right)^2$$

$$\left[(120\pi C)^{-2}\right]^{-1/2} = \left((120 \times 10^5)^2 - (100.3K)^2\right)^{-1/2}$$

$$C = \frac{1}{\left[(120\times 10^5)^2 - (100.3K)^2\right]^{1/2} 120\pi} = 221\text{ pF}$$

NOTE R HAS LITTLE EFFECT ON ANSWER

14.17)



$$V = \left| \frac{1}{j(2\pi \times 60)\times 25\times 10^{-9}} + 100.5K \right| \times 0.075$$

$$= \left| -j7,957.74 + 7,537.5 \right|$$

$$\doteq 10,961 \text{ V}$$