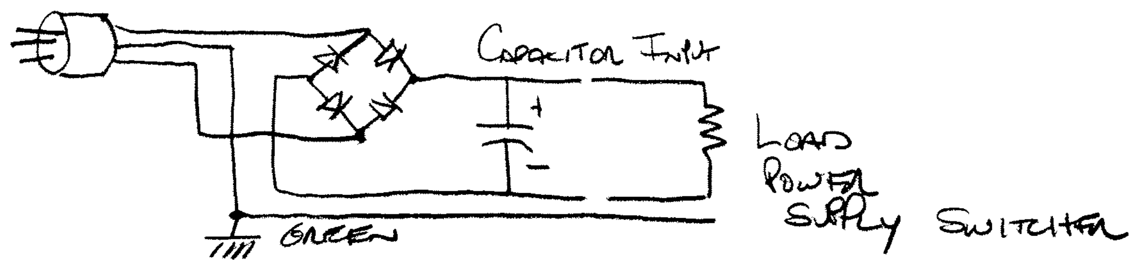
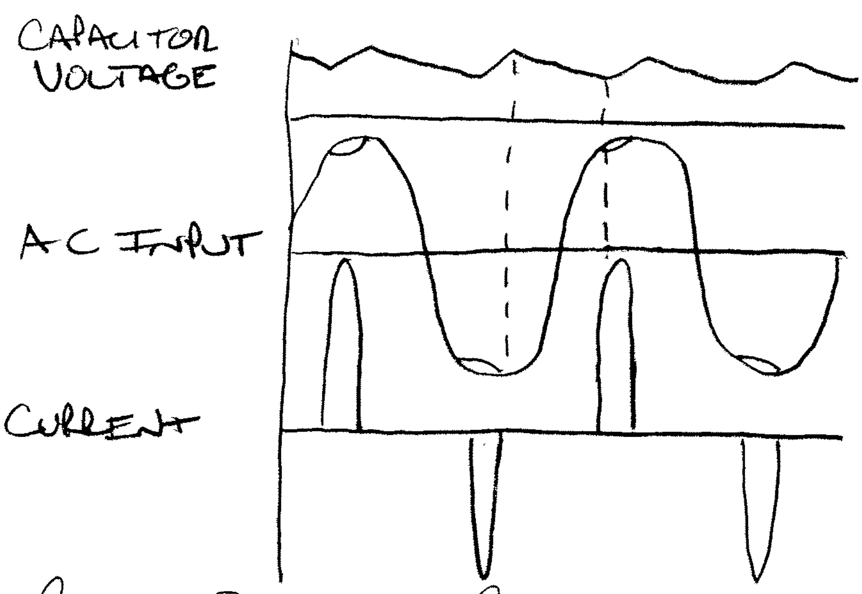
PROBLEM 33.15 | Ken Kaiser | [redacted]

WITH A SWITCHING POWER SUPPLY THERE ARE PERIODS OF CURRENT SURGES. WHY? THE POWER FACTOR IS DEFINED TO BE THE RATIO OF THE REAL POWER TO THE APPARENT POWER. ALTHOUGH THE CURRENT AND VOLTAGE ARE IN-PHASE WITH THE SWITCHING POWER SUPPLY, THE POWER FACTOR IS NOT ONE. WHY? WHAT IS ANOTHER MAJOR CONSEQUENCE OF THE CURRENT SURGES [CORP]?

- A SUDDEN INCREASE IN CURRENT CAUSES A RESULTING CHANGE IN THE MAGNETIC FIELD SURROUNDING THE CONDUCTOR, WHICH CAN INDUCE VOLTAGE CHANGES IN NEARBY CONDUCTORS.
- CONDUCTED VOLTAGE SPIKES $V = L\,di/dt$, A FAST RISE TIME (di/dt) IT CAN BE RADIATED, CAUSING AN RF SPIKE
- CURRENT SURGES ARE PRESENT TO KEEP THE CAPACITOR CHARGED TO A MINIMUM VALUE.



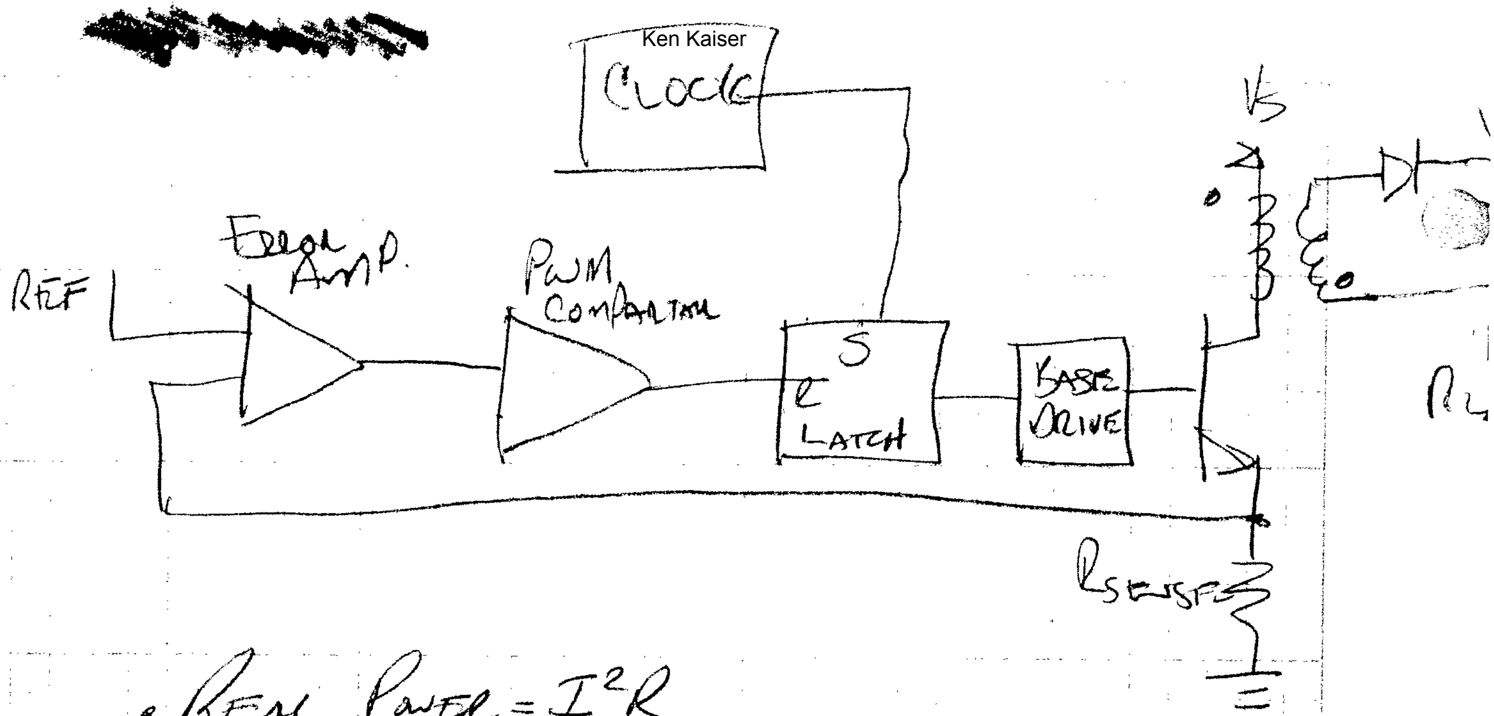


- THIS RESULTS IN CURRENT PEAKS THAT ARE SEVERAL TIMES HIGHER THAN A NORMAL CONSTANT IMPEDANCE LOAD RESISTIVE LOAD WHOULD DRAW. BUT THEY ARE SHORT DURATION.

PF = 1 ALL RESISTIVE

- POWER FACTOR $= \dfrac{P_r}{P_a} = \dfrac{\text{REAL POWER}}{\text{APPARENT POWER}}$ HENCE, THE APPARENT POWER IS MUCH HIGHER THAN THE REAL INPUT CURRENT, EVEN THOUGH THEY ARE IN PHASE. SINCE POWER FACTOR IS DEFINED AS P_r/P_a, THIS EFFECT RESULTS IN LOW POWER FACTOR.

[redacted]



- REAL POWER $= I^2 R$

  $= E_{RMS} I_{RMS} \cos\theta$ WATT (RESOLVED FOR REAL POWER)

- APPARENT POWER $= EI$ (VA) E & I are OUT OF PHASE

$$\frac{P_R}{P_A} = \cos\theta$$

- ANY DISTORTION OF THE AC VOLTAGE OR CURRENT SINE WAVE RESULTS IN A LESS THAN UNITY POWER FACTOR. (A POWER FACTOR OF 1 IS PERFECT)

"TRADITIONALLY A POOR POWER FACTOR WAS THE RESULT OF A PHASE SHIFT BETWEEN VOLTAGE AND CURRENT DUE TO INDUCTIVE OR CAPACITIVE LOADS. HOWEVER, IN THE CASE OF SWITCHING POWER SUPPLIES, THE POOR POWER FACTOR IS USUALLY THE RESULT OF A LOAD CURRENT WAVESHAPE THAT IS NOT A SINUSOIDAL WAVE YET IS STILL IN PHASE WITH THE INPUT." THE PROBLEM IS THAT IN THE CASE OF INPUT AC POWER TO A SWITCHING POWER SUPPLY, THE APPARENT CIRCUIT LOAD IMPEDANCE APPEARS TO CHANGE DURING AN AC CYCLE, RESULTING IN VERY COMPLEX PROBLEMS.

IF I_p & V_p ARE CONSTANT, THEN THE POWER UNDER THE CURVE IS, (PEAK POWER)

$$P_p = E_p I_p$$

- AVE POWER, $P_{AV} = \frac{1}{t}\int_0^t iv\,dt$

AVE POWER $\neq$ APPARENT POWER

- REAL POWER $= A_p = I_{ir} E_p$

WHERE I_{ir} = REAL INPUT CURRENT (APPARENT)
E_p = PEAK INSTAN. VOLTAGE AT THAT MOMENT IN TIME.

- APPARENT POWER $= I_{L\,APPARENT}\, V_{INSTAN.}$
NO DUTY CYCLE (ACCOUNT)

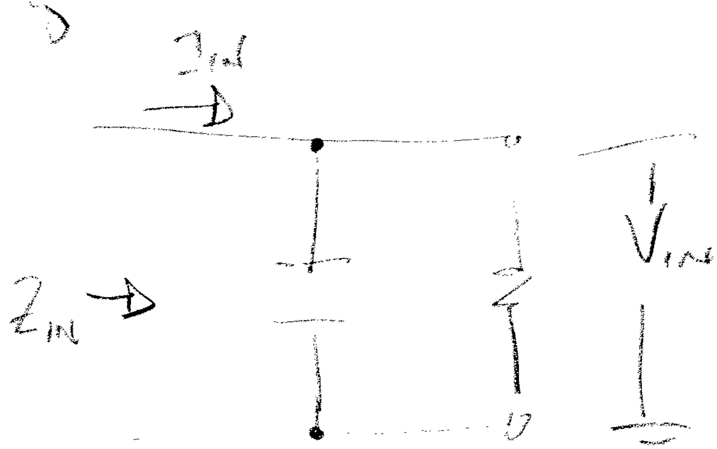
- SWITCHING CHANGES THE LOAD CONDITIONS AND MUST ALWAYS PRODUCE TRANSIENTS.

Ken Kaiser [redacted]

33-14) EE632

Power line sags can be caused [redacted]
intentionally when the power company
must shut down certain generators but consumption
rate stays the same causing a general shortage of Power.
This lowered voltage in devices that
operate on a fixed amount of power
requires that more current must flow
into the device. In the case of
computers which have active voltage
regulation circuitry the additional current
may cause more radiated magnetic noise
from this circuitry.

17 #8



$$Z_{IN} = \frac{V_{IN}}{I_{IN}}$$

NOTE: UNLESS CERTAIN THAT NETWORK IS WHOLLY RESISTIVE, SHORT/OPEN CIRCUIT TESTS DO NOT YEILD MAX/MIN VALUES OF $Re\{Z_{IN}\}$

SHORT: $Z_{IN} = 0$

OPEN: I IS WHOLLY IMAGINARY $Re\{Z_{IN}\} = 0$

THEREFORE Z_{IN} IS TOTALLY REACTIVE.

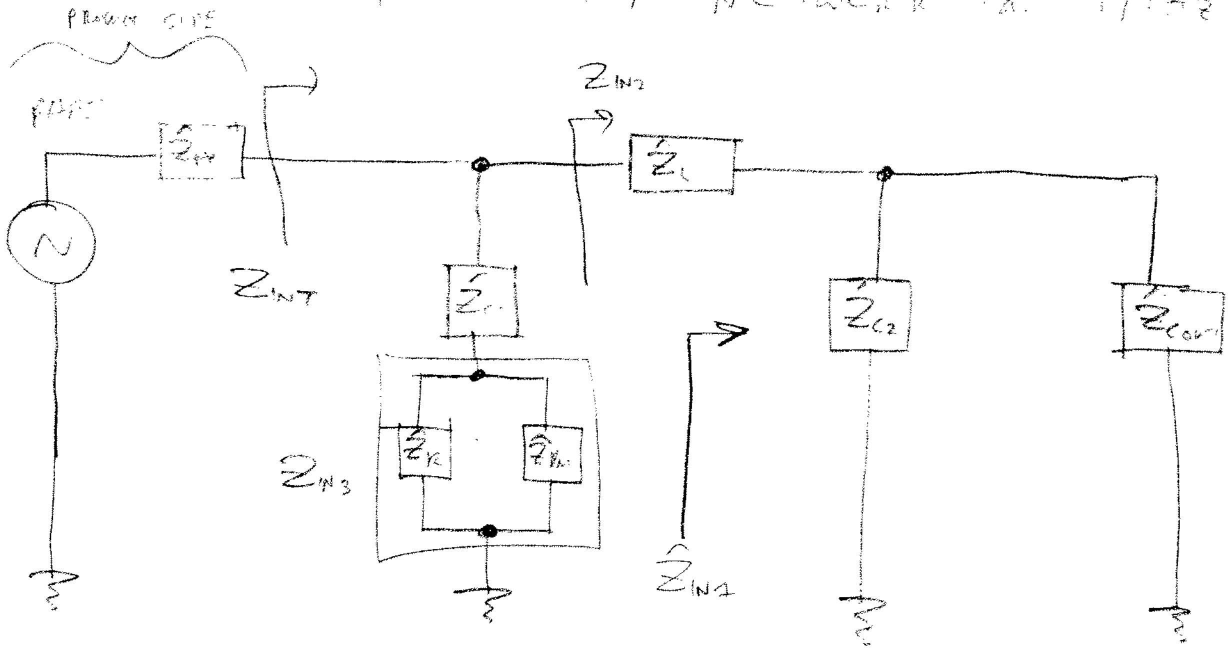
WITH REAL LOAD, Z HAS REAL & IMAGINARY COMPONENT.

Z_{IN} HAS REAL COMPONENT.

Z_{IN}, REAL WILL BE GREATEST WITH SOME FINITE, REAL LOAD.

Ken Kaiser [redacted]

Problem 17-9 LISN NETWORK @ 1MHz



Problem 17-9: LISN Network @ 1 MHz

$f := 1 \cdot 10^{6}$ $\quad \omega := 2 \cdot \pi \cdot f$ $\quad L := 50 \cdot 10^{-6}$ $\quad C_2 := 1 \cdot 10^{-6}$ $\quad C_1 := 1 \cdot 10^{-7}$

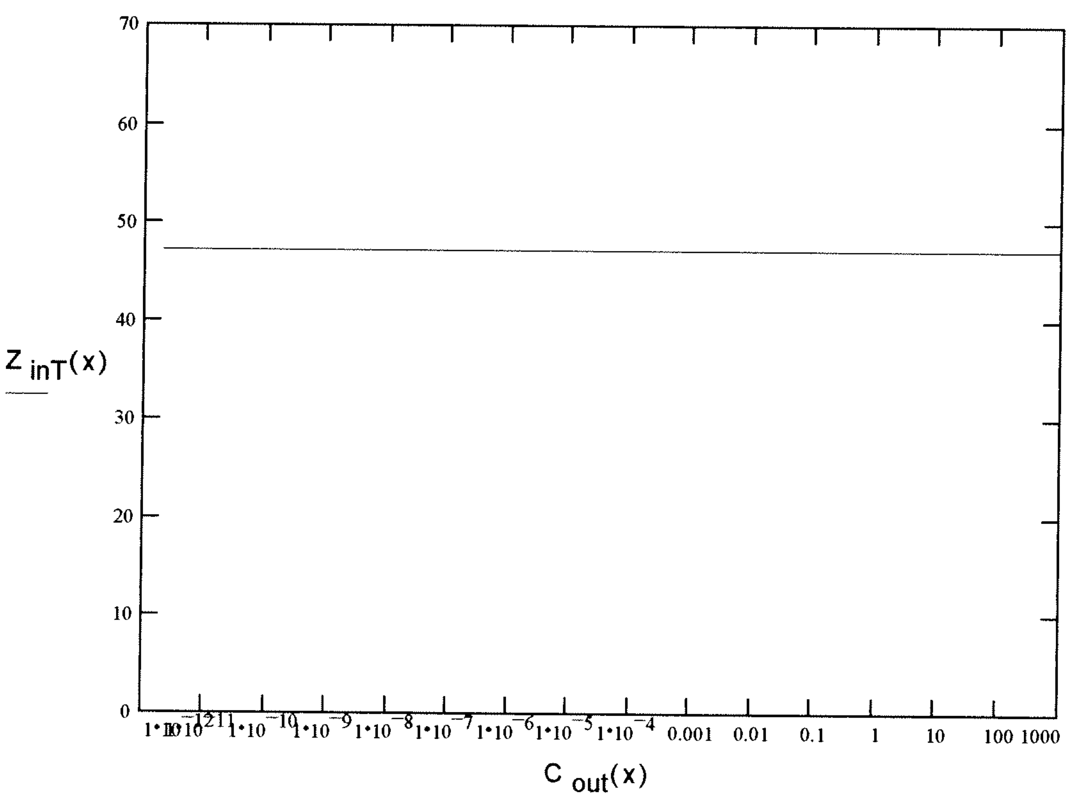
$R_m := 50$ $\quad R := 1000$

$x := 1, 2 .. 150$ $\quad C_{out}(x) := \left(x + 1 - 10 \cdot \mathrm{floor}\left(\frac{x}{10}\right)\right) \cdot 10^{\mathrm{floor}\left(\frac{x}{10}\right) - 12}$ $\quad j := \sqrt{-1}$

$$Z_{in1}(x) := \frac{1}{j \cdot \omega \cdot \left(C_{out}(x) + C_2\right)} \qquad Z_{in2}(x) := j \cdot \omega \cdot L + Z_{in1}(x)$$

$$Z_{c1} := \frac{1}{j \cdot \omega \cdot C_1} \qquad Z_{in3} := \frac{R \cdot R_m}{R + R_m}$$

$$Z_{inT}(x) := \frac{\left(Z_{in3} + Z_{c1}\right) \cdot Z_{in2}(x)}{Z_{in3} + Z_{c1} + Z_{in2}(x)} \qquad \left|Z_{inT}(70)\right| = 47.342$$



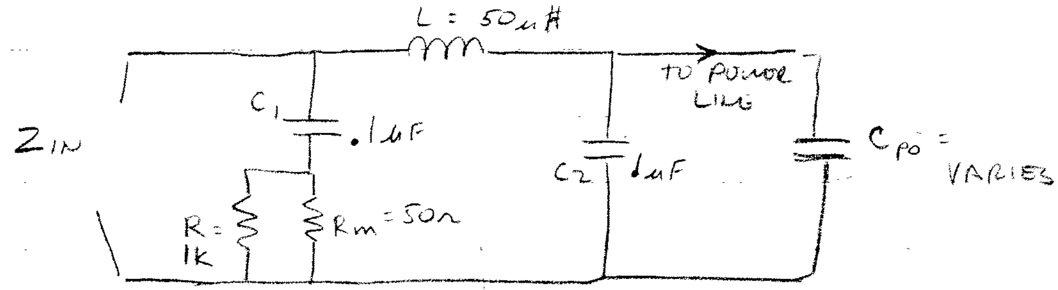
Ken Kaiser

ECE-640 WEEK 6 [redacted]

17-9 MAXIMUM INPUT IMPEDANCE OF LISN

- DETERMINE INPUT IMPEDANCE OF LISN @ 1MHZ FROM THE PRODUCT SIDE BETWEEN HOT & GND IF THE IMPEDANCE OF THE POWER OUTLET IS CAPACITIVE.

LISN (HOT & GROUND ONLY) CIRCUIT



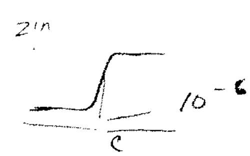
$$Z_{in} = \left[\left(Z_{C2} \parallel Z_{C_{PO}} \right) + Z_L \right] \parallel \left[Z_{C_1} + (R \parallel R_m) \right]$$

SIMPLIFIED IN MATHCAD,
EQN & PLOT ATTACHED

=

- Zin VARIES FROM;

C_{PO} (FARAD)	$\lvert Z_{in} \rvert$ (OHM)
$10^{-12} < C_{PO} < 10^{-8}$	$\simeq 47.34156$
$10^{-8} < C_{PO} < 10^{-4}$	$= 47.34156 - 47.34199$
$10^{-4} < C_{PO}$	$\simeq 47.34199$



REASON, $L \simeq 315\,\Omega$ AT 1 MHZ

1 MHZ RESONANCE? $(10^6)2(\pi) = \frac{1}{\sqrt{LC}}$ $C = \frac{1}{(L)(10^6 2\pi)^2}$ $C = 5 \times 10^{-12}$

ECE-640 Proble~~m 15-3~~ 17.9 A[redacted]

[redacted]

$x := .5, .51 .. 180$ $\qquad j := \sqrt{-1}$ $\qquad \omega := 10^{6} \cdot 2 \cdot \pi$

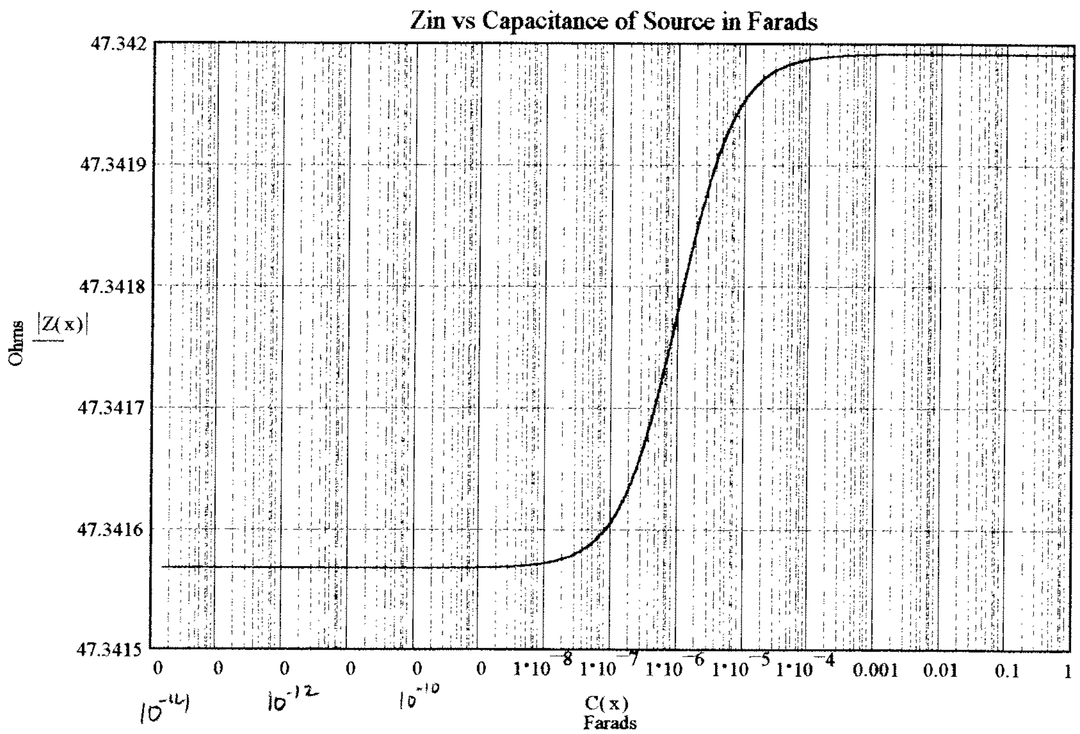
$$C(x) := \left(x + 1 - 10 \cdot \text{floor}\left(\frac{x}{10}\right)\right) \cdot 10^{\text{floor}\left(\frac{x}{10}\right)} \cdot 10^{-14}$$

$L := 50 \cdot 10^{-6}$ $\qquad R := 1000$ $\qquad R_m := 50$ $\qquad C_1 := .1 \cdot 10^{-6}$ $\qquad C_2 := 1 \cdot 10^{-6}$

$Z_{C1} := \dfrac{1}{j \cdot \omega \cdot C_1}$ $\qquad Z_{C2} := \dfrac{1}{j \cdot \omega \cdot C_2}$ $\qquad Z_C(x) := \dfrac{1}{j \cdot \omega \cdot C(x)}$ $\qquad Z_L := j \cdot \omega \cdot L$

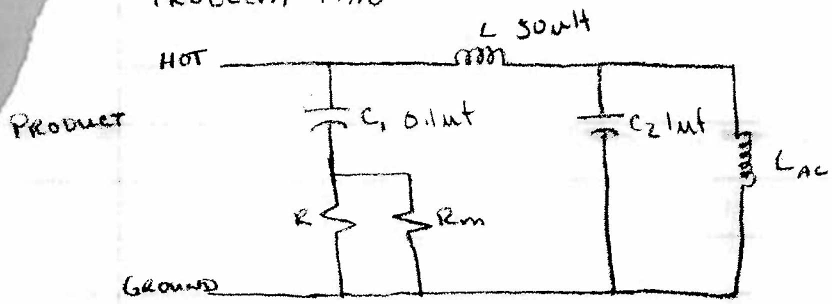
$$Z(x) := \frac{\left(\frac{Z_{C2} \cdot Z_C(x)}{Z_{C2} + Z_C(x)} + Z_L\right) \cdot \left(\frac{R \cdot R_m}{R + R_m} + Z_{C1}\right)}{\left(\frac{Z_{C2} \cdot Z_C(x)}{Z_{C2} + Z_C(x)} + Z_L\right) + \left(\frac{R \cdot R_m}{R + R_m} + Z_{C1}\right)}$$

$Z\left(10^{-3}\right) = 47.013 + 5.566i$



[redacted]

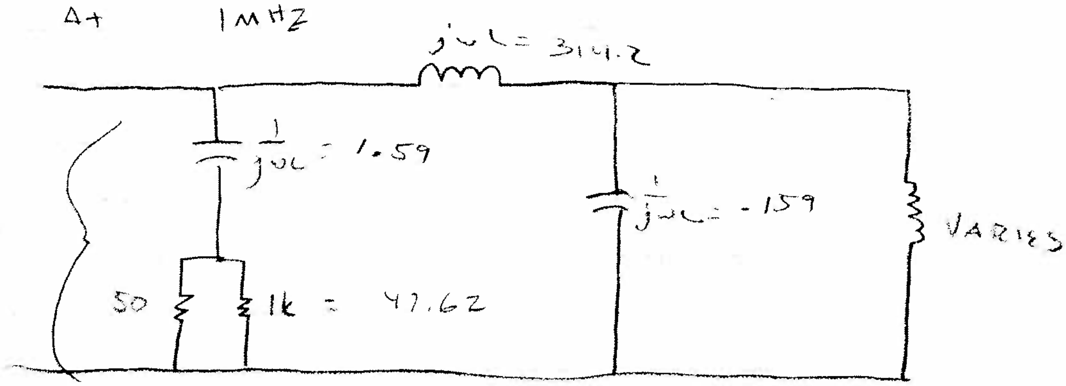
PROBLEM 17.10



$$\frac{R\cdot R_m}{R+R_m} + \frac{1}{j\omega C_1} // j\omega L + \left(\frac{1}{j\omega C_2} // j\omega L_{AC}\right)$$

$L = 50\mu H$ $C_2 = 1\mu F$ $C_1 = 0.1\mu F$ $R_m = 50\,\Omega$ $R = 1K\Omega$ L_{AC} VARIES

At 1MHZ



THE FIRST GROUP OF MATHCAD PLOTS SHOW THE INPUT IMPEDANCE at 1MHZ, Looking in at the product side, as the Inductor LOAD IS VARIED THROUGH A LARGE RANGE OF FREQUENCIES

THE FINAL 3 PAGES SHOW THE INPUT IMPEDANCE AS A FUNCTION OF FREQUENCY WITH A Inductor LOAD OF 50uH; NOTICE AT LOW FREQUENCIES HOW THE INPUT IMPEDANCE VARIES SIGNIFICANTLY AND IS UNPREDICTABLE.

$j := \sqrt{-1}$ $\quad L := 50 \cdot 10^{-6}$ $\quad \omega := 2 \cdot \pi \cdot 1 \cdot 10^{6}$ Ken Kaiser

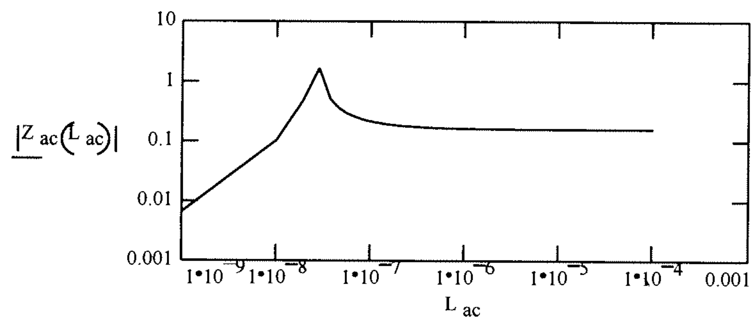
$C_1 := .1 \cdot 10^{-6}$ $\quad C_2 := 1 \cdot 10^{-6}$ $\quad L_{ac} := 1 \cdot 10^{-9}, 10 \cdot 10^{-9} .. 100 \cdot 10^{-6}$

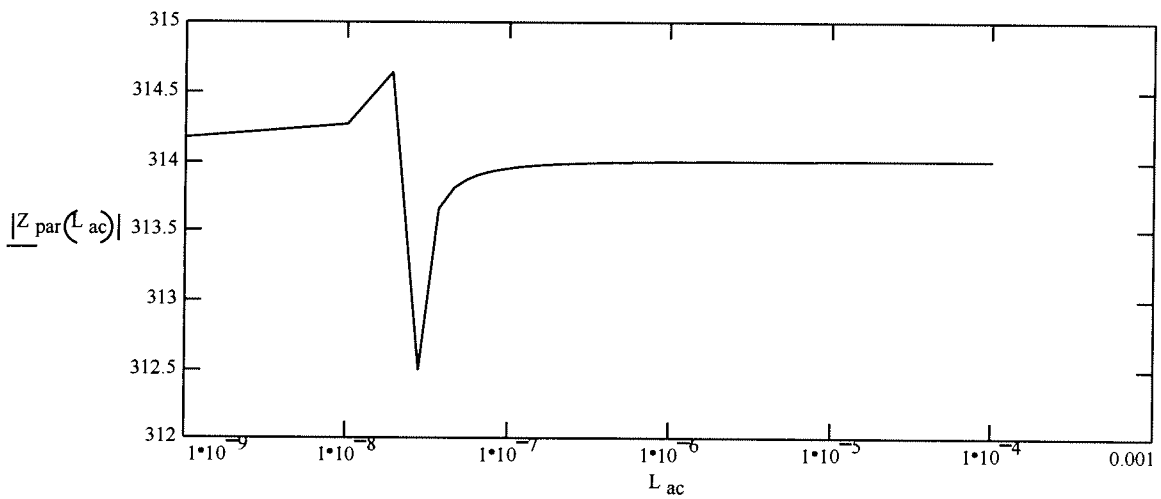
$R := 1000$ $\quad R_m := 50$

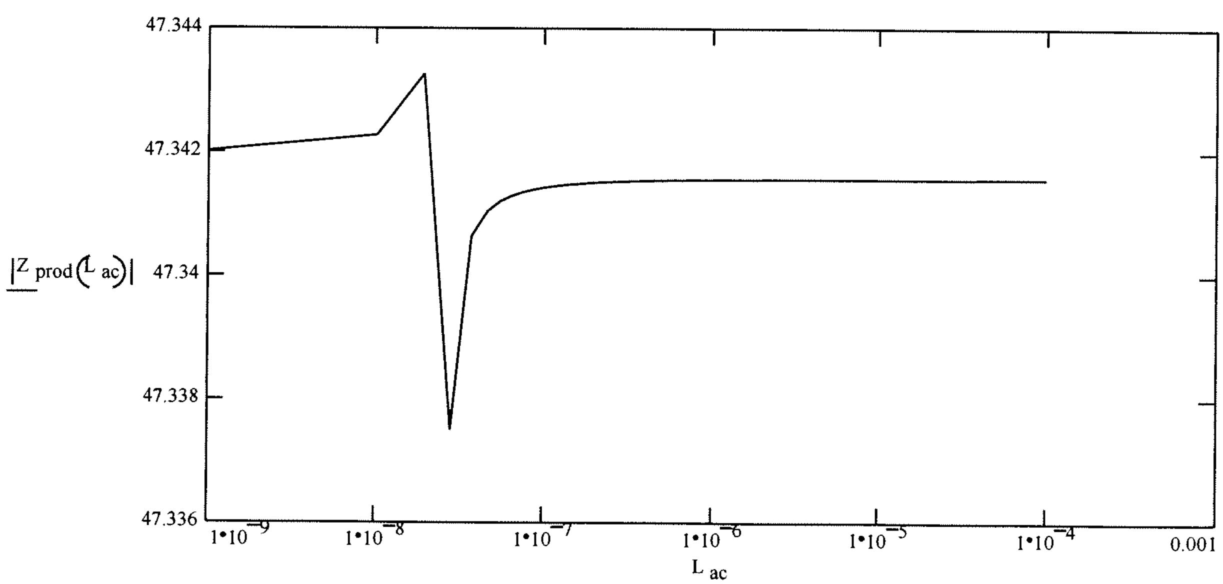
$$Z_r := \left(\frac{R \cdot R_m}{R + R_m} + \frac{1}{j \cdot \omega \cdot C_1} \right) \qquad Z_{ac}(L_{ac}) := \frac{j \cdot \omega \cdot L_{ac} \cdot \frac{1}{j \cdot \omega \cdot C_2}}{j \cdot \omega \cdot L_{ac} + \frac{1}{j \cdot \omega \cdot C_2}} \qquad Z_{par}(L_{ac}) := j \cdot \omega \cdot L + Z_{ac}(L_{ac})$$

$|Z_r| = 47.646$

$$Z_{prod}(L_{ac}) := \frac{Z_r \cdot Z_{par}(L_{ac})}{Z_r + Z_{par}(L_{ac})}$$







$j := \sqrt{-1}$ $\quad L := 50\cdot 10^{-6}$ $\quad C_1 := .1\cdot 10^{-6}$ $\quad C_2 := 1\cdot 10^{-6}$ Ken Kaiser

$R := 1000 \qquad R_m := 50$

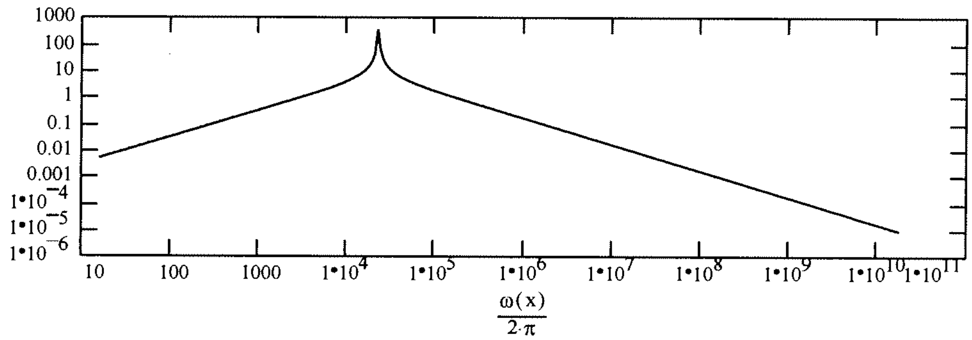
$x := 20, 20.1 .. 110$

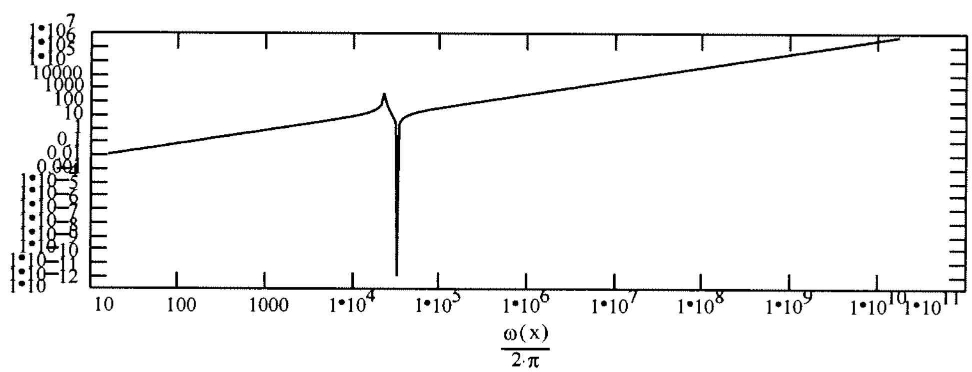
$$\omega(x) := \left(x + 1 - 10\cdot \mathrm{floor}\left(\frac{x}{10}\right)\right)\cdot 10^{\mathrm{floor}\left(\frac{x}{10}\right)}$$

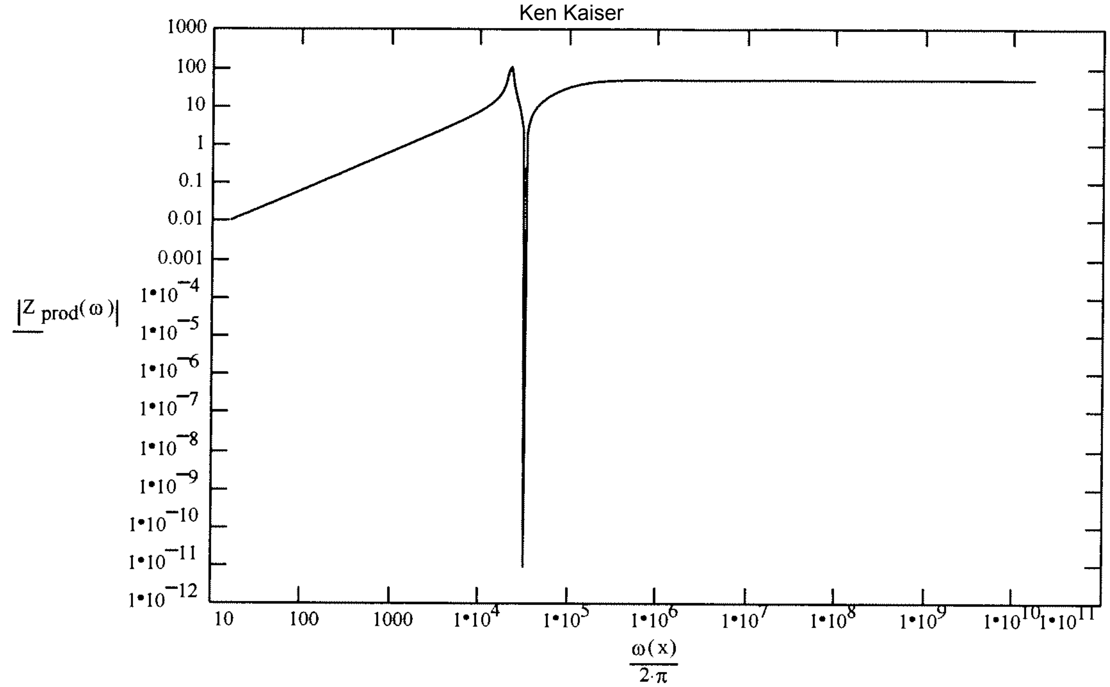
$$Z_r(\omega) := \left(\frac{R\cdot R_m}{R + R_m} + \frac{1}{j\cdot\omega(x)\cdot C_1}\right) \qquad Z_{ac}(\omega) := \frac{j\cdot\omega(x)\cdot L\cdot\frac{1}{j\cdot\omega(x)\cdot C_2}}{j\cdot\omega(x)\cdot L + \frac{1}{j\cdot\omega(x)\cdot C_2}}$$

$$Z_{par}(\omega) := j\cdot\omega(x)\cdot L + Z_{ac}(\omega)$$

$$Z_{prod}(\omega) := \frac{Z_r(\omega)\cdot Z_{par}(\omega)}{Z_r(\omega) + Z_{par}(\omega)}$$






Ken Kaiser
1000
100
10
1
0.1
0.01
0.001
1•10−4
1•10−5
1•10−6
1•10−7
1•10−8
1•10−9
1•10−10
1•10−11
1•10−12
|Z prod(ω)|
10
100
1000
1•10^4
1•10^5
1•10^6
1•10^7
1•10^8
1•10^9
1•10^10
1•10^11
ω(x) / 2·π

$j := \sqrt{-1}$ $\quad L := 50\cdot 10^{-6}$ $\quad C_1 := .1\cdot 10^{-6}$ $\quad C_2 := 1\cdot 10^{-6}$ Ken Kaiser

$R := 1000$ $\quad R_m := 50$

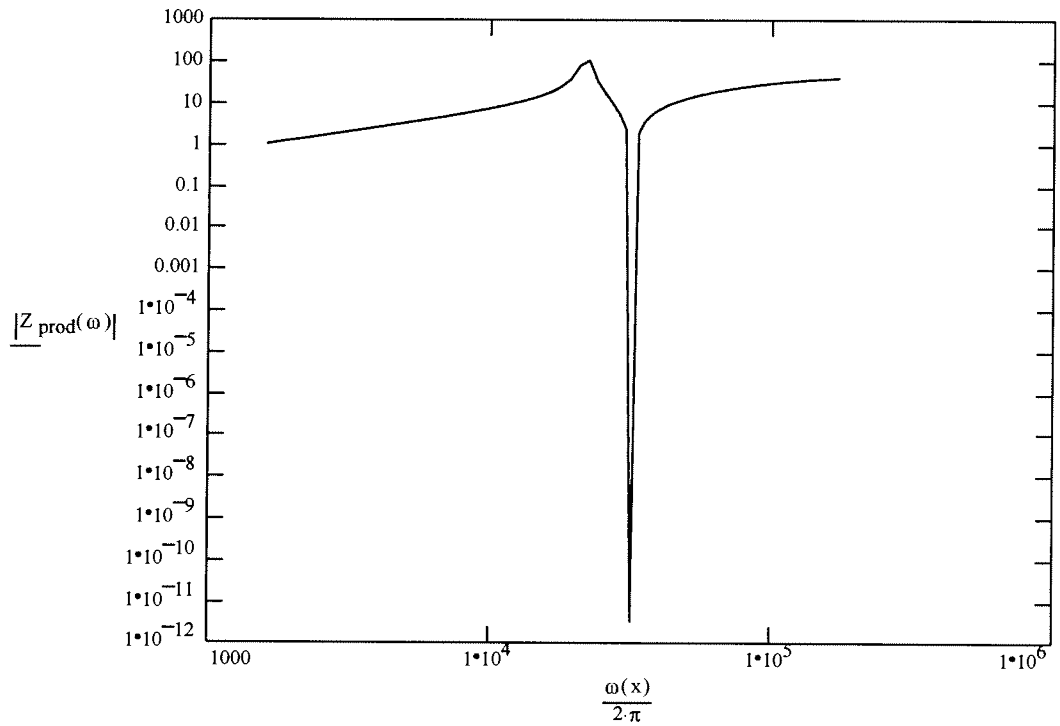
$x := 40, 40.1 .. 60$

$$\omega(x) := \left(x + 1 - 10\cdot \mathrm{floor}\left(\frac{x}{10}\right)\right)\cdot 10^{\mathrm{floor}\left(\frac{x}{10}\right)}$$

$$Z_r(\omega) := \left(\frac{R\cdot R_m}{R + R_m} + \frac{1}{j\cdot\omega(x)\cdot C_1}\right) \qquad Z_{ac}(\omega) := \frac{j\cdot\omega(x)\cdot L\cdot\frac{1}{j\cdot\omega(x)\cdot C_2}}{j\cdot\omega(x)\cdot L + \frac{1}{j\cdot\omega(x)\cdot C_2}}$$

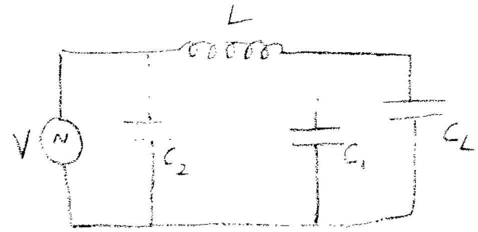
$$Z_{par}(\omega) := j\cdot\omega(x)\cdot L + Z_{ac}(\omega)$$

$$Z_{prod}(\omega) := \frac{Z_r(\omega)\cdot Z_{par}(\omega)}{Z_r(\omega) + Z_{par}(\omega)}$$

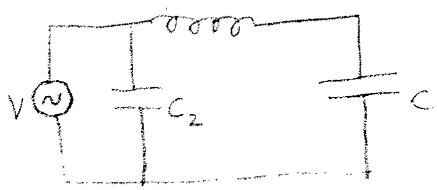


Ken Kaiser [redacted]

7.) The equivalent circuit between hot and ground is



$\Downarrow$



$C = C_1 + C_L$

Equivalent Impedance is $\left[j\omega L + \dfrac{1}{j\omega C}\right] \Big\| \left(\dfrac{1}{j\omega C_2}\right)$

$$= \left(\frac{-\omega^2 LC + 1}{j\omega C}\right) \Big\| \left(\frac{1}{j\omega C_2}\right)$$

$$= \frac{\left(\dfrac{1-\omega^2 LC}{j\omega C}\right)\left(\dfrac{1}{j\omega C_2}\right)}{\left(\dfrac{1-\omega^2 LC}{j\omega C}\right) + \dfrac{1}{j\omega C_2}}$$

$$= \frac{1-\omega^2 LC \,/\, -\cancel{\omega^2} C C_2}{(1-\omega^2 LC)\, j\omega C_2 + j\omega C \,/\, -\cancel{\omega^2} C C_2}$$

$$= \frac{1-\omega^2 LC}{j\omega C_2 - j\omega^3 LCC_2 + j\omega C} = \frac{1-\omega^2 LC}{j(\omega C_2 - \omega^3 LCC_2 + \omega C)}$$

$$= \frac{-j(1-\omega^2 LC)}{\omega C_2 - \omega^3 LCC_2 + \omega C}$$

Equating imaginary parts to zero Ken Kaiser

$$1 - \omega^2 LC = 0$$

$$1 = \omega^2 LC$$

$$\omega^2 = \frac{1}{\sqrt{LC}}$$

$\therefore$ resonant frequency $f = \dfrac{1}{2\pi\sqrt{LC}}$

$$= \frac{1}{2\pi\sqrt{L(C_L + C_1)}}$$

$$\Rightarrow \quad C_L = \frac{1}{4\pi^2 f^2 L} - C_1$$

$$C_1 = 0.1 \times 10^{-6} \quad \& \quad L = 50 \times 10^{-6}$$

Since the whole range is negative, we can say that there are no positive real values of C_L that can cause a resonance over the 450 KHz to 30 MHz operating range

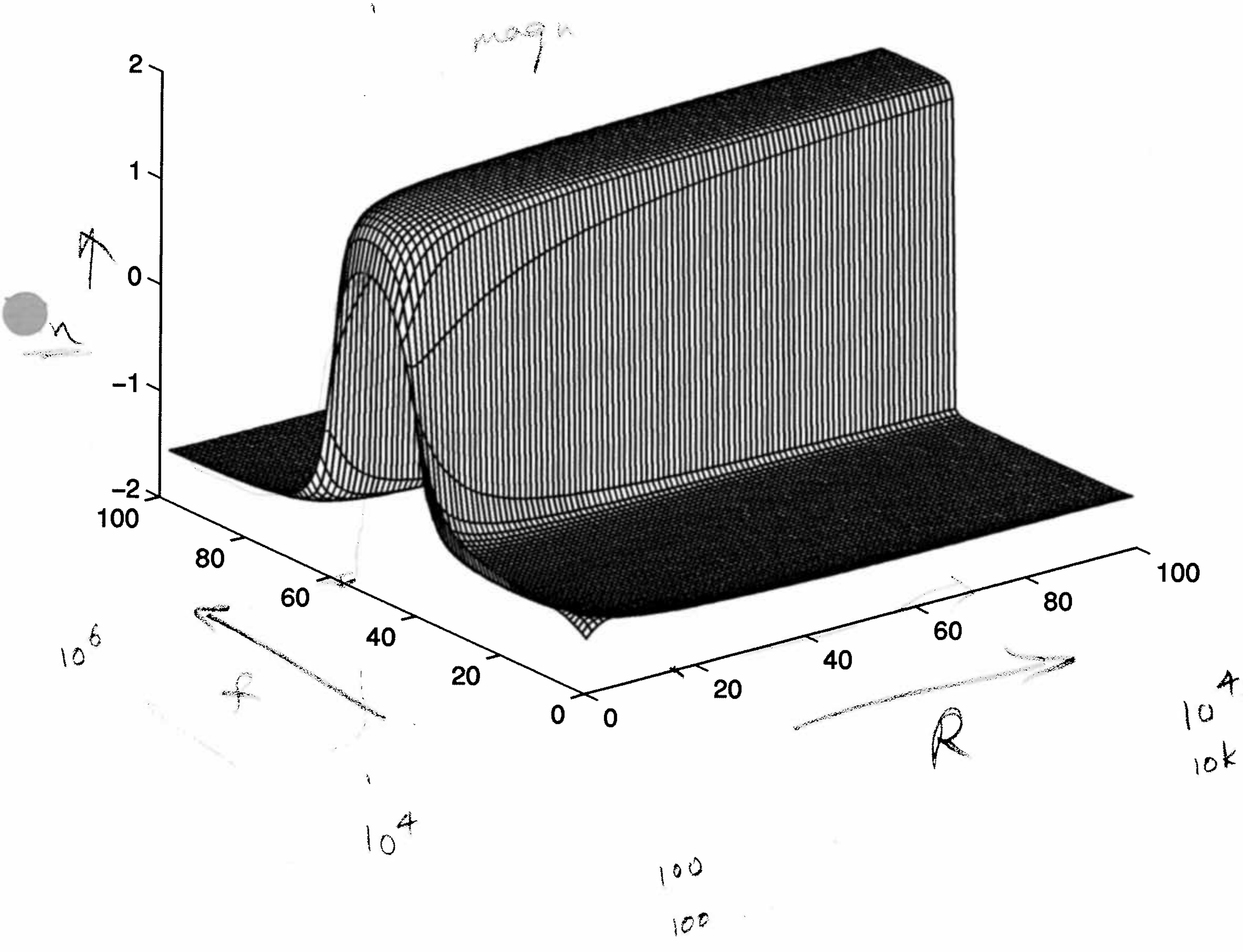
Taking the resistances into consideration we see that the input impedance is $\frac{1}{j\omega C_2} \,\|\, \left[j\omega L + \left[\left(\frac{1}{j\omega C_1} + R_1 \right) \| \frac{1}{j\omega C_L} \right] \right]$ where $R_1 = \frac{R R_m}{R + R_m}$

When this input impedance was plotted along with ω and the resistance in a three-dimensional plot, It was found that R didnot have a significant effect on the resonant frequency. But it did have a pronounced effect on the magnitude & phase.

```
C1=0.1*10^(-6);
C2=0.1*10^(-6);
LL=1.1*10^(-6);
L=50*10^(-6);

Z=zeros(99,100);


for w=10^4+10000:10000:10^6

        for R=100:100:10^4

                Z( (w-10^4)/10000 , R/100 )=( ( ((1/(i*w*C1))+R)*((i*w*LL)) )/( ((1/(i*w*C1))+

        end
w
end
```

Ken Kaiser

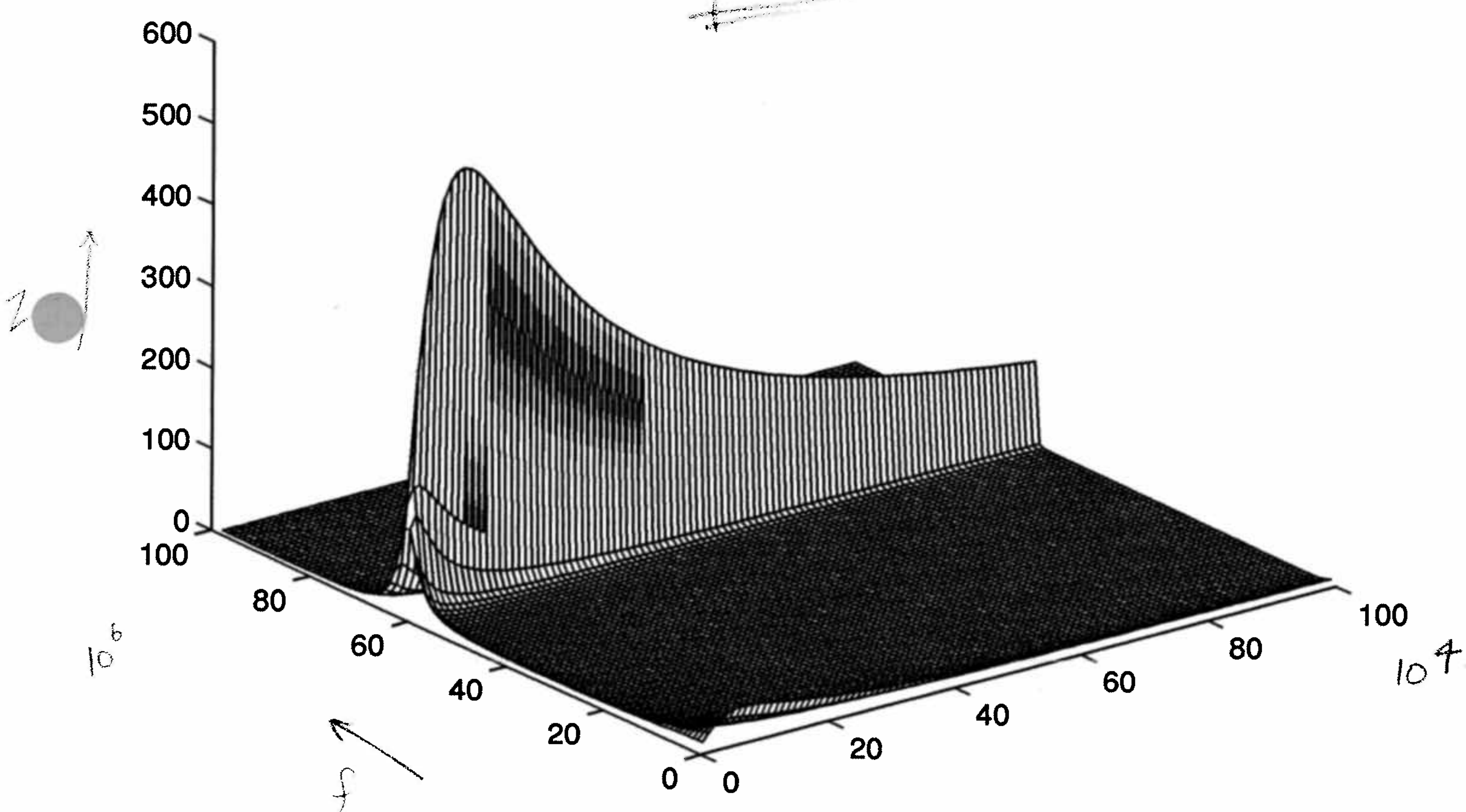
Magnitude (Z_{in})



Ken Kaiser

phase(Zin)

phase



10^4 100

$C1 := .1\cdot 10^{-6}$ $\quad C2 := .1\cdot 10^{-6}$ $\quad R := 1\cdot 10^{3}$ $\quad Rm := 50$ $\quad j := \sqrt{-1}$ $\quad x := 50, 50.5 .. 100$

Ken Kaiser

Vi Luu
sec17-6

$Zl := 0$

$$w(x) := \left(x + 1 - 10\cdot \mathrm{floor}\left(\frac{x}{10}\right)\right)\cdot 10^{\mathrm{floor}\left(\frac{x}{10}\right)}$$

To block out frequency range up to 60 MHz L must be:

$$L := \frac{9400}{(60\cdot 10^{6}\cdot 2\cdot \pi)} \qquad L = 2.493\cdot 10^{-5}$$

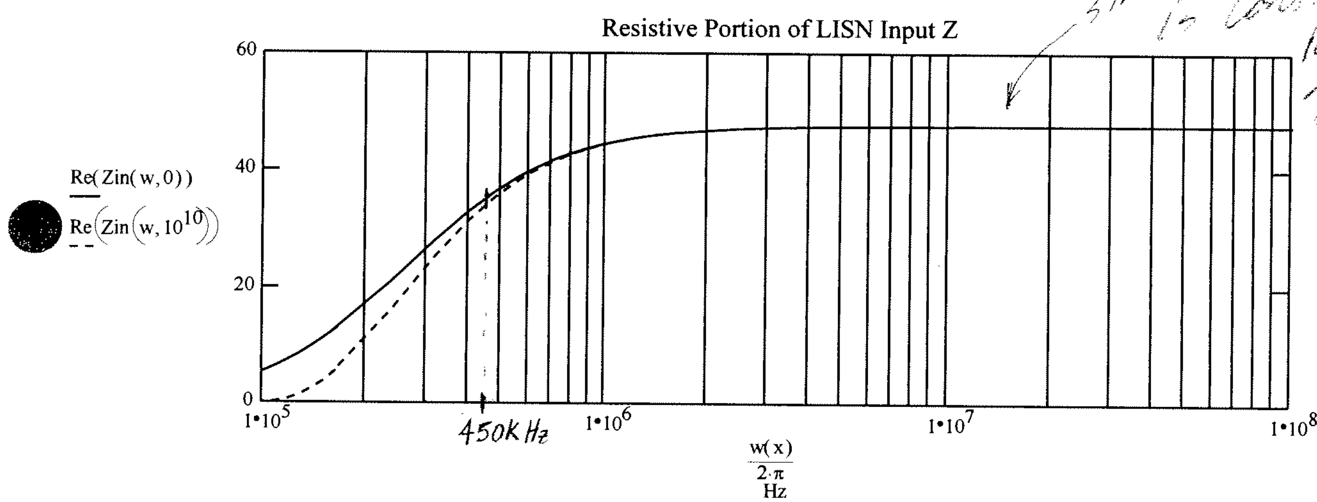
Increase the frequency(from 30 MHz) range of impedance by 2 reduces the inductance by 2.

$$L = \frac{50\cdot 10^{-6}}{2}$$

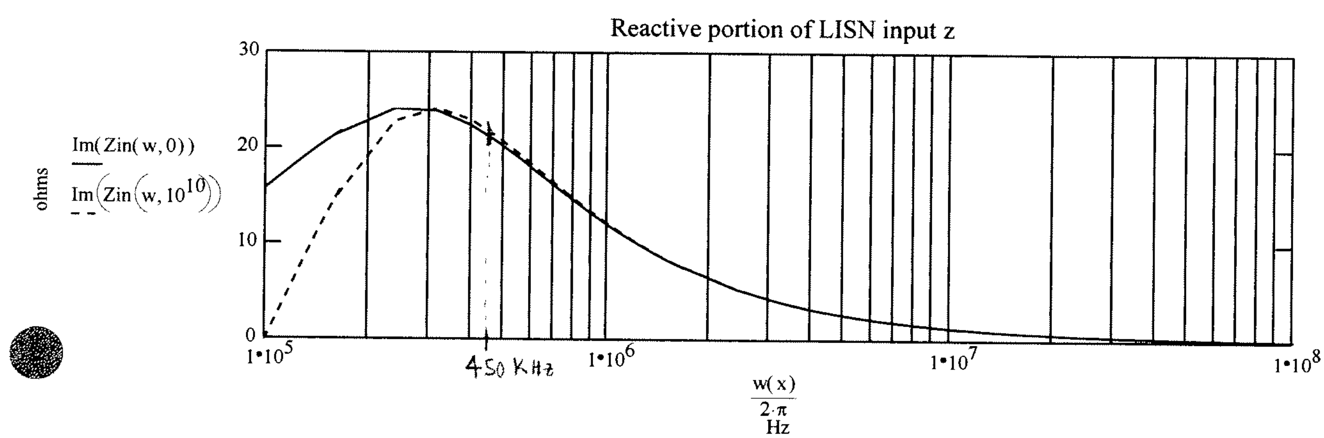
Analysis using section 17-6 for frequency range 450 kHz to 60 MHz; Impedance looking from the product side. Short and open circuit analysis of the load at the output supply side.

$$Zin(w, Zl) := \frac{\left[\dfrac{\dfrac{Zl}{j\cdot w(x)\cdot C2}}{Zl + \dfrac{1}{j\cdot w(x)\cdot C2}} + j\cdot w(x)\cdot L\right]\cdot\left(\dfrac{1}{j\cdot w(x)\cdot C1} + R\cdot\dfrac{Rm}{R + Rm}\right)}{\left[\dfrac{\dfrac{Zl}{j\cdot w(x)\cdot C2}}{Zl + \dfrac{1}{j\cdot w(x)\cdot C2}} + j\cdot w(x)\cdot L\right] + \left(\dfrac{1}{j\cdot w(x)\cdot C1} + R\cdot\dfrac{Rm}{R + Rm}\right)}$$

Since the upper range is constant there's really no need to change.



The Impedance gives little variance from under open and short circuit output load for the real part.



The Impedance gives little variance(frequency greater than 300 KHz) for the imaginary part.

V i C U D

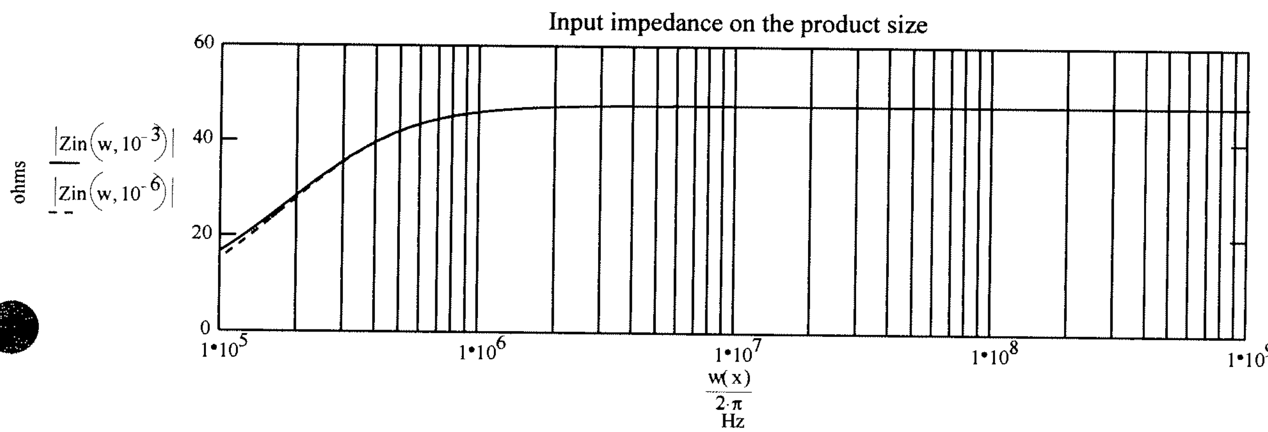
$C1 := .1\cdot 10^{-6}$ $C2 := .1\cdot 10^{-6}$ $R := 1\cdot 10^{3}$ $Rm := 50$ Ken Kaiser $j := \sqrt{-1}$ $x := 50, 50.5 .. 100$

$$L := \frac{50\cdot 10^{-6}}{2} \qquad Zl(w, Cl) := \frac{1}{j\cdot w(x)\cdot Cl} \qquad Cl := 1\cdot 10^{-6} \qquad w(x) := \left(x + 1 - 10\cdot \mathrm{floor}\left(\frac{x}{10}\right)\right)\cdot 10^{\mathrm{floor}\left(\frac{x}{10}\right)}$$

Analysis of section 17-8

Similar analysis is done with an capacitive load.

$$Zin(w, Cl) := \frac{\left[\dfrac{\dfrac{Zl(w,Cl)}{j\cdot w(x)\cdot C2}}{Zl(w,Cl) + \dfrac{1}{j\cdot w(x)\cdot C2}} + j\cdot w(x)\cdot L\right]\cdot\left(\dfrac{1}{j\cdot w(x)\cdot C1} + R\cdot\dfrac{Rm}{R+Rm}\right)}{\left[\dfrac{\dfrac{Zl(w,Cl)}{j\cdot w(x)\cdot C2}}{Zl(w,Cl) + \dfrac{1}{j\cdot w(x)\cdot C2}} + j\cdot w(x)\cdot L\right] + \left(\dfrac{1}{j\cdot w(x)\cdot C1} + R\cdot\dfrac{Rm}{R+Rm}\right)}$$



Overall the circuit's response is flat over the frequency of 450 KHz to 60 MHz under resistive and capacitive load at the output side. The previous example in the book also meet the specification ? beyond 30 MHz

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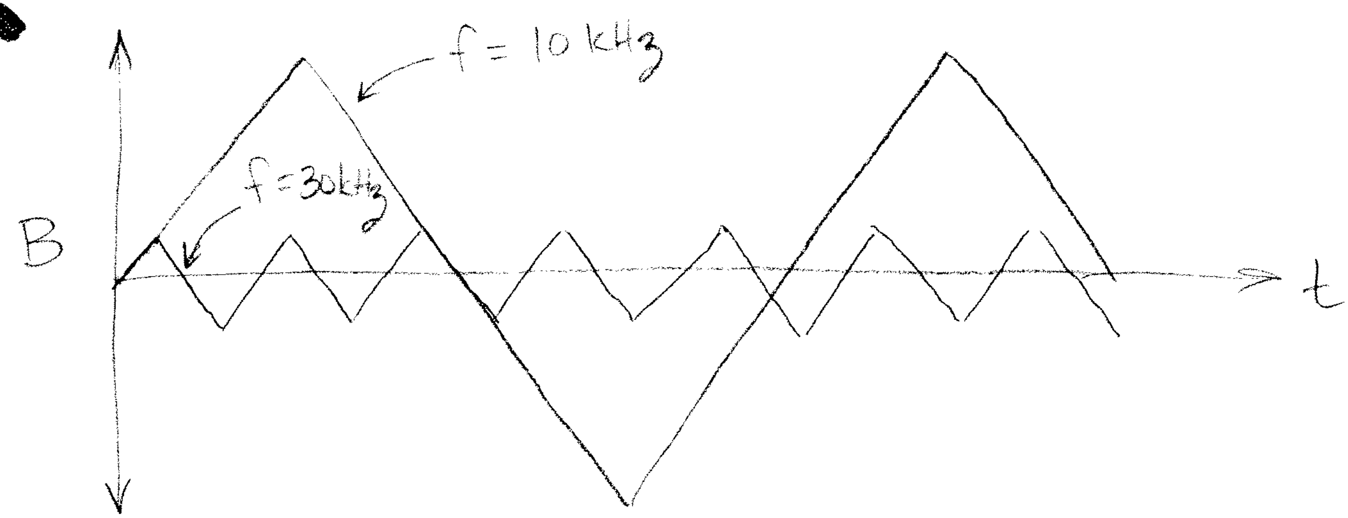
[redacted]

17-1) EE632

Lenz's law says that a changing flux at a given rate causes a corresponding voltage to appear at the inductor terminals. In a switching supply the desired output is fixed thus the rate of flux change is fixed. From the following diagram it can be seen that for a fixed rate of flux change the B fields get much larger in a slower switching supply.



Finally, to support the larger B fields without saturating the core, the transformer must have more magnetic core material and thus be physically larger. Typical switching frequencies vary from 20 kHz to 100 kHz.

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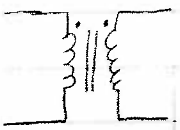
Section 17

(11) Work Problem 17.11

According to Faraday's Law: $V = -N \frac{\partial \phi}{\partial t}$



if voltage variation is sinusoidal, mag. flux also vaires sinusoidally under ideal conditions

$$\phi = \phi_m \sin \omega t$$

Now,

$$V = -N\omega \phi_m \cos \omega t$$

Since $\phi = B \cdot A$

$$V = -N\omega B \cdot A \cos \omega t = -N 2\pi \underset{\uparrow}{f} B \underset{\downarrow}{A} \cos \omega t$$

V - want same

N - same

f - increases

Area needs to be decreased when frequency is increased to get same output voltage

If frequency is increased 10x, area can be reduced by 10x

Typical frequencies of switching power supplies:
10kHz to 1MHz [Nave pg. 2]

 [redacted]

SECTION 26 PROBLEM 8

The non linear nature of the mic is being stressed because when radiation is coupled through non linear objects then the radiation is comprised of multiple frequencies do to clipping of the wave. When a sinusoidal of on frequency  is CLIPPED 

The resultant waveform is NOT sinusoidal And thus it is comprised of many frequencies

Since the Load is 600Ω = Low impedance an inductor can be used in series to create a low pass filter. CB frequencies range between 27MHz and 29MHz. The frequencies found on a telephone channel are between 300 Hz to 3400Hz with the majority of the voice signals in the kilohertz range.

Any Resonable size Inductor can be used since the frequencies of interest are low compared to the Interference of CB's

Frequency of interest 300 to 3400kHz = 1885 to 21,362.8 $\frac{1}{\text{sec}}$

Frequency to be filtered 27MHz to 29MHz = 169.6×10^6 to 182.21×10^6 $\frac{1}{\text{sec}}$

Impedance $= j\omega L$ we want this to be >> 600Ω

so pick INDUCTOR IN MILLIHENRY REGION

$Z = j\omega L$ at $\omega = 2\cdot\pi\cdot 28\times10^6$ Hz $L = 1\times10^{-3}$ Henries. $Z = 175{,}929\,\Omega$

$L = 1\times10^{-4}$ Henries $Z = 17.5929\,k\Omega$

$L = 1\times10^{-5}$ Henries $Z = 1.759\,k\Omega$

COULD AS PICK INDUCTOR IN 0.1 MILLIHENRY REGION. OR EVEN IN 10 mH Region.

$\boxed{I = 100mH \text{ DOWN to } 10mH}$

Not sig(Ω)

Conductive Emission Nonlinearities

$$I_o + c_1\cdot[A\cdot(1 + M\cdot\cos(\Omega\cdot t))\cdot\cos(\omega\cdot t)] + c_2\cdot[A\cdot(1 + M\cdot\cos(\Omega\cdot t))\cdot\cos(\omega\cdot t)]^2 + c_3\cdot[A\cdot(1 + M\cdot\cos(\Omega\cdot t))\cdot\cos(\omega\cdot t)]^3$$

$$I_o + c_1\cdot A\cdot\cos(\omega\cdot t) + c_1\cdot A\cdot\cos(\omega\cdot t)\cdot M\cdot\cos(\Omega\cdot t) + c_2\cdot A^2\cdot\cos(\omega\cdot t)^2 + 2\cdot c_2\cdot A^2\cdot\cos(\omega\cdot t)^2\cdot M\cdot\cos(\Omega\cdot t) + c_2\cdot A^2\cdot\cos(\omega\cdot t)^2\cdot M^2\cdot\cos(\Omega\cdot t)^2 + c_3\cdot A^3\cdot\cos($$

$$I_o + c_1\cdot A\cdot\cos(\omega\cdot t) + c_1\cdot A\cdot\cos(\omega\cdot t)\cdot M\cdot\cos(\Omega\cdot t) + c_2\cdot A^2\cdot\frac{1+\cos(2\cdot\omega\cdot t)}{2} + 2\cdot c_2\cdot A^2\cdot\frac{1+\cos(2\cdot\omega\cdot t)}{2}\cdot M\cdot\cos(\Omega\cdot t) + c_2\cdot A^2\cdot\frac{1+\cos(2\cdot\omega\cdot t)}{2}\cdot M^2\cdot\frac{1+\cos(}{2}$$

$$\boxed{I_o} + \boxed{c_1\cdot A\cdot\cos(\omega\cdot t)} + \boxed{c_1\cdot A\cdot\cos(\omega\cdot t)\cdot M\cdot\cos(\Omega\cdot t)} + \boxed{\frac{1}{2}\cdot c_2\cdot A^2} + \boxed{\frac{1}{2}\cdot c_2\cdot A^2\cdot\cos(2\cdot\omega\cdot t)} + \boxed{c_2\cdot A^2\cdot M\cdot\cos(\Omega\cdot t)} + \boxed{c_2\cdot A^2\cdot M\cdot\cos(\Omega\cdot t)\cdot\cos(2\cdot\omega\cdot t)} + \boxed{\frac{1}{4}\cdot c_2\cdot A^2 M^2} +$$

$$I_o + \frac{1}{2}c_2A^2 + \frac{1}{4}c_2A^2M^2 + c_2A^2M\cos(\Omega t) + \frac{1}{4}c_2A^2M^2\cos(2\Omega t)$$

$$+ A\Big[c_1M\cos(\Omega t) + \frac{3}{4}c_3A^2 + \frac{9}{4}c_3A^2\cos(\Omega t) + c_1 + \frac{9}{8}c_3A^2M^2 + \frac{9}{8}c_3A^2M^2\cos(2\Omega t) + \frac{9}{16}c_3A^2M^3\cos(\Omega t) + \frac{3}{16}c_3A^2M^3\cos(3\Omega t)\Big]\cos(\omega t)$$

$$^{3} + 3\cdot c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M\cdot\cos(\Omega\cdot t) + 3\cdot c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^2\cdot\cos(\Omega\cdot t)^2 + c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^3\cdot\cos(\Omega\cdot t)^3$$

$$\frac{\cdot\Omega\cdot t)}{} + c_3\cdot A^3\cdot\frac{3\cdot\cos(w\cdot t) + \cos(3\cdot\omega\cdot t)}{4} + 3\cdot c_3\cdot A^3\cdot\frac{3\cdot\cos(w\cdot t) + \cos(3\cdot\omega\cdot t)}{4}\cdot M\cdot\cos(\Omega\cdot t) + 3\cdot c_3\cdot A^3\cdot\frac{3\cdot\cos(w\cdot t) + \cos(3\cdot\omega\cdot t)}{4}\cdot M^2\cdot\frac{1+\cos(2\cdot\Omega\cdot t)}{2} + c_3\cdot A^3\cdot\cdot$$

$$\boxed{+\frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\Omega\cdot t)} \boxed{+\frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\omega\cdot t)} \boxed{+\frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\omega\cdot t)\cdot\cos(2\cdot\Omega\cdot t)} \boxed{+\frac{3}{4}\cdot c_3\cdot A^3\cdot\cos(w\cdot t)} \boxed{+\frac{1}{4}\cdot c_3\cdot A^3\cdot\cos(3\cdot\omega\cdot t)} \boxed{+\frac{9}{4}\cdot c_3\cdot A^3\cdot M\cdot\cos(\Omega t)\cos(\omega t)}$$

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$$\left[\frac{1}{2}C_2A^2 + C_2A^2M\cos(\Omega t) + \frac{1}{4}C_2A^2M^2 + \frac{1}{4}C_2A^2M^2\cos(2\Omega t) + \cancel{\frac{3}{8}C_3A^3 M}\right]\cos(2\omega t)$$

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$$\frac{3\cdot\cos(w\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M^3\cdot\frac{3\cdot\cos(\Omega\cdot t)+\cos(3\cdot\Omega\cdot t)}{4}$$

$$\Omega\cdot 4\cos(w\cdot t)+\boxed{\frac{3}{4}\cdot c_3\cdot A^3\cdot M\cdot\cos(\Omega\cdot t)\cdot\cos(3\cdot\omega\cdot t)}+\boxed{\frac{9}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(w\cdot t)}+\boxed{\frac{9}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(w\cdot t)\cdot\cos(2\cdot\Omega\cdot t)}+\boxed{\frac{3}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(3\cdot\omega\cdot t)}+\boxed{\frac{3}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(3\omega t)\cos(2\Omega t)}$$

$$\left[\frac{1}{4}C_3A^3+\frac{3}{4}C_3A^3M\cos(\Omega t)+\frac{3}{8}C_3A^3M^2+\frac{3}{8}C_3A^3M^2\cos(2\Omega t)+\frac{3}{16}C_3A^3M^3\cos(\Omega t)\right]\cos(3\omega t)+\frac{1}{16}C_3A^3M^3\cos(3\Omega t)$$

$$\cos\left(\cancel{3\cdot\omega\cdot t}\right)\cdot\cos\left(\cancel{2\cdot\Omega\cdot t}\right)+\boxed{\frac{9}{16}\cdot c_3\cdot A^3\cdot M^3\cdot\cos(w\cdot t)\cdot\cos(\Omega\cdot t)}+\boxed{\frac{3}{16}\cdot c_3\cdot A^3\cdot M^3\cdot\cos(w\cdot t)\cdot\cos(3\cdot\Omega\cdot t)}+\boxed{\frac{3}{16}\cdot c_3\cdot A^3\cdot M^3\cdot\cos(3\cdot\omega\cdot t)\cdot\cos(\Omega\cdot t)}+\frac{1}{16}\cdot c_3\cdot A^3\cdot M^3\cdot\cos\left(\cancel{3\cdot\omega t}\right)\cos(3\Omega t)$$

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$\cancel{(\cdot t \cdot \cos(3 \cdot 2 \cdot t)}$

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$$I_o + c_1 \cdot [A \cdot (1 + M \cdot \sin(\Omega \cdot t)) \cdot \cos(\omega \cdot t)] + c_2 \cdot [A \cdot (1 + M \cdot \sin(\Omega \cdot t)) \cdot \cos(\omega \cdot t)]^2 + c_3 \cdot [A \cdot (1 + M \cdot \sin(\Omega \cdot t)) \cdot \cos(\omega \cdot t)]^3$$

$$I_o + c_1 \cdot A \cdot \cos(\omega \cdot t) + c_1 \cdot A \cdot \cos(\omega \cdot t) \cdot M \cdot \sin(\Omega \cdot t) + c_2 \cdot A^2 \cdot \cos(\omega \cdot t)^2 + 2 \cdot c_2 \cdot A^2 \cdot \cos(\omega \cdot t)^2 \cdot M \cdot \sin(\Omega \cdot t) + c_2 \cdot A^2 \cdot \cos(\omega \cdot t)^2 \cdot M^2 - c_2 \cdot A^2 \cdot \cos(\omega \cdot t)^2 \cdot M^2 \cdot \cos(\Omega \cdot t)^2 + c_3 \cdot A^3 \cdot \cos(\omega \cdot t)^3 + 3 \cdot c_3 \cdot A^3 \cdot \cos(\omega \cdot t)^3 \cdot M \cdot \sin$$

$$I_o + c_1 \cdot A \cdot \cos(\omega \cdot t) + c_1 \cdot A \cdot \cos(\omega \cdot t) \cdot M \cdot \sin(\Omega \cdot t) + c_2 \cdot A^2 \cdot \frac{1 + \cos(2 \cdot \omega \cdot t)}{2} + 2 \cdot c_2 \cdot A^2 \cdot \frac{1 + \cos(2 \cdot \omega \cdot t)}{2} \cdot M \cdot \sin(\Omega \cdot t) + c_2 \cdot A^2 \cdot \frac{1 + \cos(2 \cdot \omega \cdot t)}{2} \cdot M^2 - c_2 \cdot A^2 \cdot \frac{1 + \cos(2 \cdot \omega \cdot t)}{2} \cdot M^2 \cdot \frac{1 + \cos(2 \cdot \Omega \cdot t)}{2} + c_3 \cdot A^3 \cdot \frac{3 \cdot \cos(}{}$$

$$\boxed{I_o} + \frac{1}{4} \cdot c_3 \cdot A^3 \cdot \cos(3 \cdot \omega \cdot t) \boxed{+ \frac{3}{4} \cdot c_3 \cdot A^3 \cdot \cos(\omega \cdot t)} + \frac{1}{2} \cdot c_2 \cdot A^2 \cdot \cos(2 \cdot \omega \cdot t) \boxed{+ c_1 \cdot A \cdot \cos(\omega \cdot t)} - \frac{3}{8} \cdot c_3 \cdot A^3 \cdot M^3 \cdot \sin(\Omega \cdot t) \cdot \cos(\omega \cdot t) \cdot \cos(2 \cdot \Omega \cdot t) - \frac{1}{8} \cdot c_3 \cdot A^3 \cdot M^3 \cdot \sin(\Omega \cdot t) \cdot \cos(3 \cdot \omega \cdot t) \cdot \cos(2 \cdot \Omega \cdot t) - \frac{9}{8} \cdot c_3 \cdot A^3 \cdot M^2 \cdot \cos(\omega \cdot t) \cdot$$

$$I_o + \frac{1}{4} C_2 A^2 M^2 + \frac{1}{2} C_2 A^2 + C_2 A^2 M \sin(\Omega t)$$

$$- \frac{1}{4} C_2 A^2 M^2 \cos(2\Omega t)$$

$$\frac{3}{4} C_3 A^2 +$$

$$\frac{3}{8} C_3 A^3 M$$

$$\ldots(\omega\cdot t)^3\cdot M\cdot\sin(\Omega\cdot t) + 3\cdot c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^2 - 3\cdot c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^2\cdot\cos(\Omega\cdot t)^2 + c_3\cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^3\cdot\sin(\Omega\cdot t) - c_3 \quad \cdot A^3\cdot\cos(\omega\cdot t)^3\cdot M^3\cdot\sin(\Omega\cdot t)\cdot\cos(\Omega\cdot t)^2$$

$$\ldots{}_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4} + 3\cdot c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M\cdot\sin(\Omega\cdot t) + 3\cdot c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M \quad {}^2 - 3\cdot c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M^2\cdot\frac{1+\cos(2\cdot\Omega\cdot t)}{2} + c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M^3\cdot\sin(\Omega\cdot t) -$$

$$\ldots M^2\cdot\cos(\omega\cdot t)\cdot\cos(2\cdot\Omega\cdot t) - \frac{3}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(3\cdot\omega\cdot t)\cdot\cos(2\cdot\Omega\cdot t) \boxed{+ \frac{3}{8}\cdot c_3\cdot A^3\cdot M^3\cdot\sin(\Omega\cdot t)\cdot\cos(\omega\cdot t)} + \frac{1}{8}\cdot c_3\cdot A^3\cdot M^3\cdot\sin(\Omega\cdot t)\cdot\cos(3\cdot\omega\cdot t) \boxed{+ \frac{9}{4}\cdot c_3\cdot A^3\cdot M\cdot\sin(\Omega\cdot t)\cdot\cos(\omega\cdot t)} + \frac{3}{4}\cdot c_3\cdot A^3\cdot M\cdot\sin(\Omega\cdot t)\cdot\cos(3\cdot\omega\cdot t) \boxed{+ \frac{9}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(\omega\cdot t)} +$$

$$\Big[\ {}^2 + C_1 A + \frac{9}{8} C_3 A^2 M^2 + C_1 A M \sin(\Omega t) + C_3 A^3 M^3 \sin(\Omega t) + \frac{9}{4} C_3 A^2 M \sin(\Omega t)\ \Big] \times \cos(\omega t)$$

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$$\ldots\mathrm{os}(2\cdot\Omega\cdot t) \over 2} + c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M^3\cdot\sin(\Omega\cdot t) - c_3\cdot A^3\cdot\frac{3\cdot\cos(\omega\cdot t)+\cos(3\cdot\omega\cdot t)}{4}\cdot M^3\cdot\sin(\Omega\cdot t)\cdot\frac{1+\cos(2\cdot\Omega\cdot t)}{2}$$

$$\frac{3}{4}\cdot c_3\cdot A^3\cdot M\cdot\sin(\Omega\cdot t)\cdot\cos(3\cdot\omega\cdot t) \boxed{+\frac{9}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(\omega\cdot t)} + \frac{3}{8}\cdot c_3\cdot A^3\cdot M^2\cdot\cos(3\cdot\omega\cdot t) - \frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\omega\cdot t)\cdot\cos(2\cdot\Omega\cdot t) \boxed{-\frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\Omega\cdot t)} \boxed{+\frac{1}{4}\cdot c_2\cdot A^2\cdot M^2} + \frac{1}{4}\cdot c_2\cdot A^2\cdot M^2\cdot\cos(2\cdot\omega\cdot t) \boxed{+c_2\cdot A^2\cdot M\cdot\sin(\Omega\cdot t)} + c_2\cdot A^2\cdot M\cdot\mathrm{sir}\ldots$$

$$\boxed{c_2 \cdot A^2 \cdot M^2 \cdot \cos(2 \cdot \Omega \cdot t)} + \boxed{\frac{1}{4} \cdot c_2 \cdot A^2 \cdot M^2} + \frac{1}{4} \cdot c_2 \cdot A^2 \cdot M^2 \cdot \cos(2 \cdot \omega \cdot t) + \boxed{c_2 \cdot A^2 \cdot M \cdot \sin(\Omega \cdot t)} + c_2 \cdot A^2 \cdot M \cdot \sin(\Omega \cdot t) \cdot \cos(2 \cdot \omega \cdot t) + \boxed{\frac{1}{2} \cdot c_2 \cdot A^2} + \boxed{c_1 \cdot A \cdot \cos(\omega \cdot t) \cdot M \cdot \sin(\Omega \cdot t)}$$