FIGURE 1

1-15-73
J McNeil

BLOCK DIAGRAM — CONSTANT POWER CONTROLLER

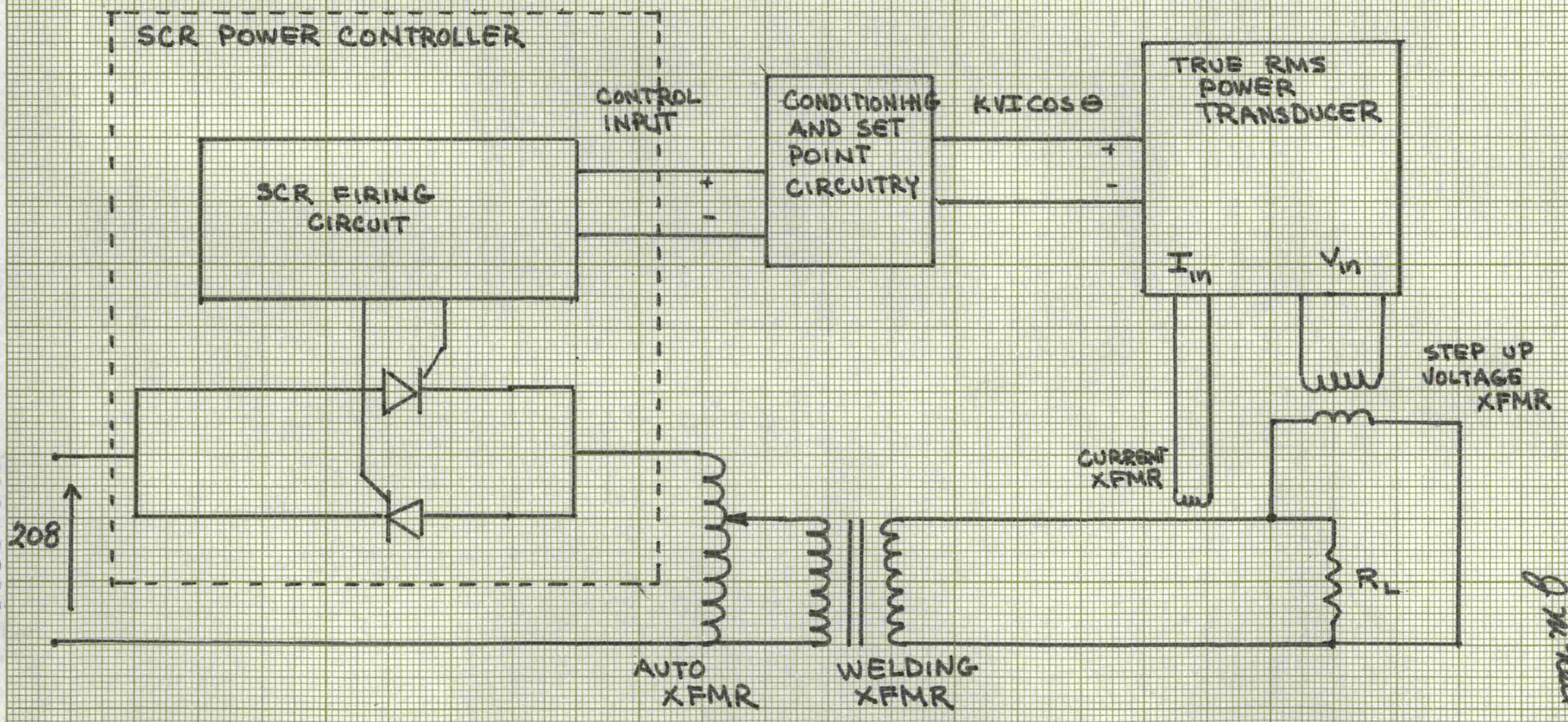
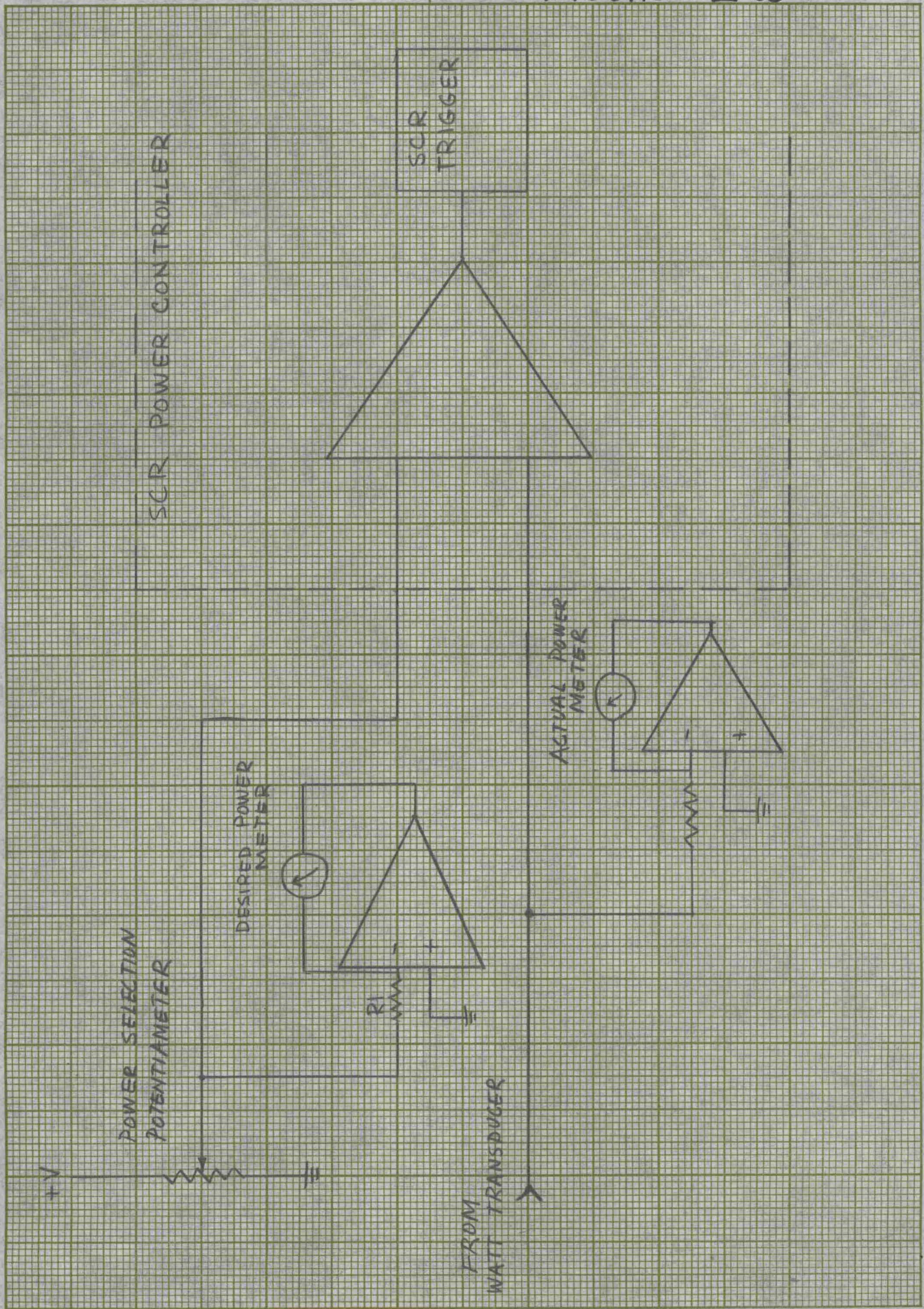


FIGURE 2a


SCR POWER CONTROLLER
SCR TRIGGER
ACTUAL POWER METER
DESIRED POWER METER
R1
POWER SELECTION
POTENTIAMETER
+V
FROM
WATT TRANSDUCER

SET POINT CIRCUITRY

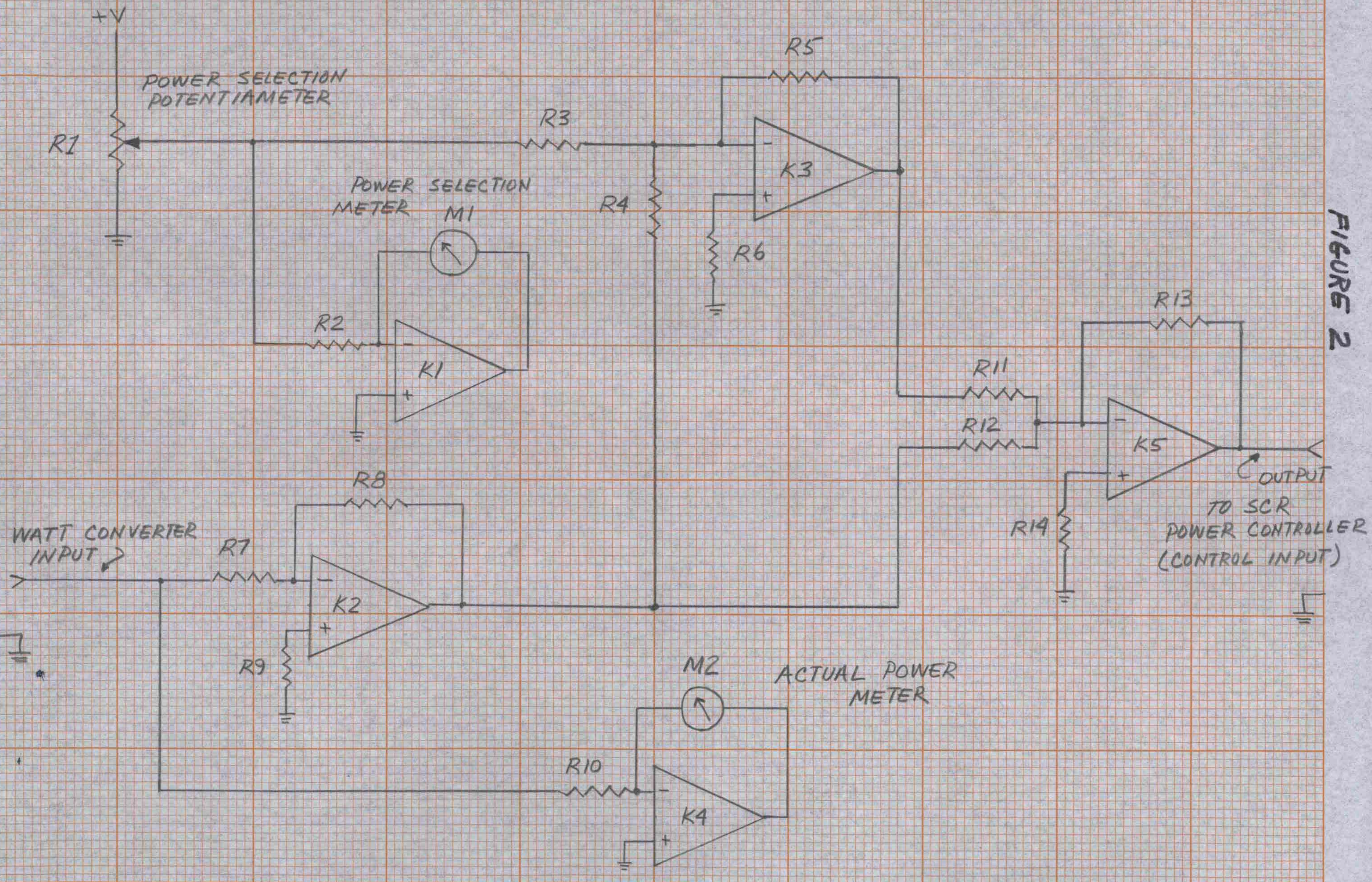
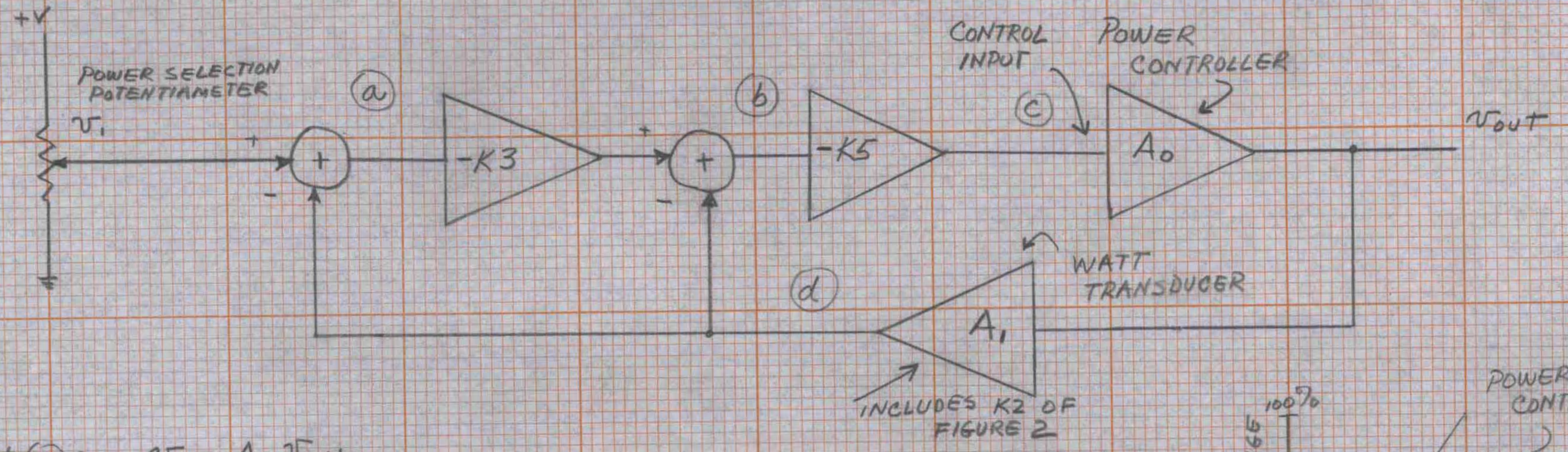


FIGURE 2



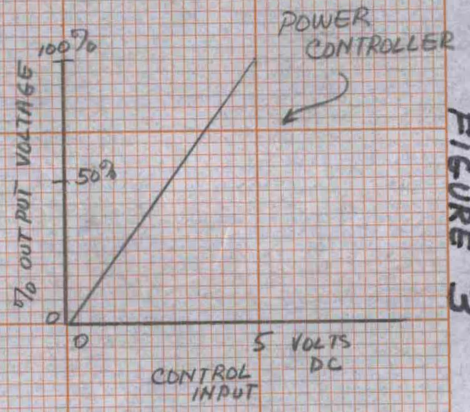


FIGURE 3

at (a): $v_1 - A_1 v_{out}$

at (b) $-K_3 v_1 + K_3 A_1 v_{out} - A_1 v_{out} = -K_3 v_1 + A_1 v_{out}(K_3 - 1)$

at (c) $+K_3 K_5 v_1 - K_5 A_1 v_{out}(K_3 - 1)$

$$v_{out} = +A_0 K_3 K_5 v_1 - A_0 A_1 (K_3 - 1) K_5 v_{out}$$

so $v_{out} + A_0 A_1 (K_3 - 1) K_5 v_{out} = A_0 K_3 K_5 v_1$

OR $$v_{out} = \frac{A_0 K_3 K_5}{1 + A_0 A_1 (K_3 - 1) K_5} v_1$$

at (d) $$\frac{A_0 A_1 K_3 K_5}{1 + A_0 A_1 (K_3 - 1) K_5} v_1 = \frac{A_0 A_1 K_3 K_5}{A_0 A_1 K_3 K_5 - A_0 A_1 K_5 + 1} v_1 = \frac{A_0 A_1 K_3 K_5}{A_0 A_1 K_3 K_5 \left(1 - \frac{1}{K_3} + \frac{1}{A_0 A_1 K_3 K_5}\right)} v_1 \approx v_1$$

if $K_3 >> 1$

THE ASSUMPTION IN FIGURE 2 WAS THAT ALL CIRCUITS HAD INFINITE BANDWIDTH; i.e., A STEP WOULD BE TRANSMITTED WITH ZERO RISE TIME. ASSUMING NOW THAT THE POWER CONTROLLER, A_0, AND THE WATT TRANSDUCER, A_1, HAVE FINITE RESPONSE TIMES, LET'S COMPUTE THE OVERALL RESPONSE TIME OF THE CIRCUIT.

FROM FIGURE (3)

$$V_{out} = \frac{A_0 K_3 K_5}{1 + A_0 A_1 K_3 K_5} V_1$$

let $A_0 = \frac{\alpha A_0}{s+\alpha}$; $\alpha = \frac{1}{2\,msec} = 500$ (response of power controller to step has time constant ~ 2 msec)

let $A_1 = \frac{\gamma A_1}{s+\gamma}$; $\gamma = \frac{1}{5\,msec} = 200$ (response of watt Transducer to step has time constant ~ 5 msec)

using Laplace Transform Techniques,

$$V_{out}(s) = \frac{\frac{\alpha A_0}{s+\alpha} K_3 K_5 \quad V_1(s)}{1 + \frac{\alpha A_0}{(s+\alpha)} \frac{\gamma A_1}{(s+\gamma)} K_3 K_5} = \frac{\alpha A_0 K_3 K_5 (s+\gamma)}{(s+\alpha)(s+\gamma) + \alpha\gamma A_0 A_1 K_3 K_5} V_1(s)$$

Since we want the response to a step in input voltage,
let $V_1(s) = \mathcal{L}[u(t)] = \frac{1}{s}$

$\therefore$

$$V_{out}(s) = \frac{\alpha A_0 K_3 K_5 (s+\gamma)}{s\left[(s+\alpha)(s+\gamma) + \alpha\gamma A_0 A_1 K_3 K_5\right]}$$

let $A_0 = 1000$ (voltage gain of power controller)

$A_1 = \frac{1}{A_0}$

$K_3 = 50$

$K_5 = 1$

$$V_{out}(s) = \frac{25\times10^6 \quad (s+200)}{s\left[s + (.35 + j\,2.21)10^3\right]\left[s + (.35 - j\,2.21)10^3\right]}$$

$$= \frac{25\times10^6 \quad (s+200)}{s\left[(s + .35\times10^3)^2 + (2.21\times10^3)^2\right]}$$

FROM Laplace transform table

$$\mathcal{L}^{-1}\left\{\frac{K\,(s+a_0)}{s[(s+\alpha)^2+\beta^2]}\right\} = K\left[\frac{a_0}{\beta_0^2} + \left(\frac{1}{\beta\beta_0}\left[(a_0-\alpha)^2+\beta^2\right]^{1/2} e^{-\alpha t}\sin(\beta t+\psi)\right)\right]$$

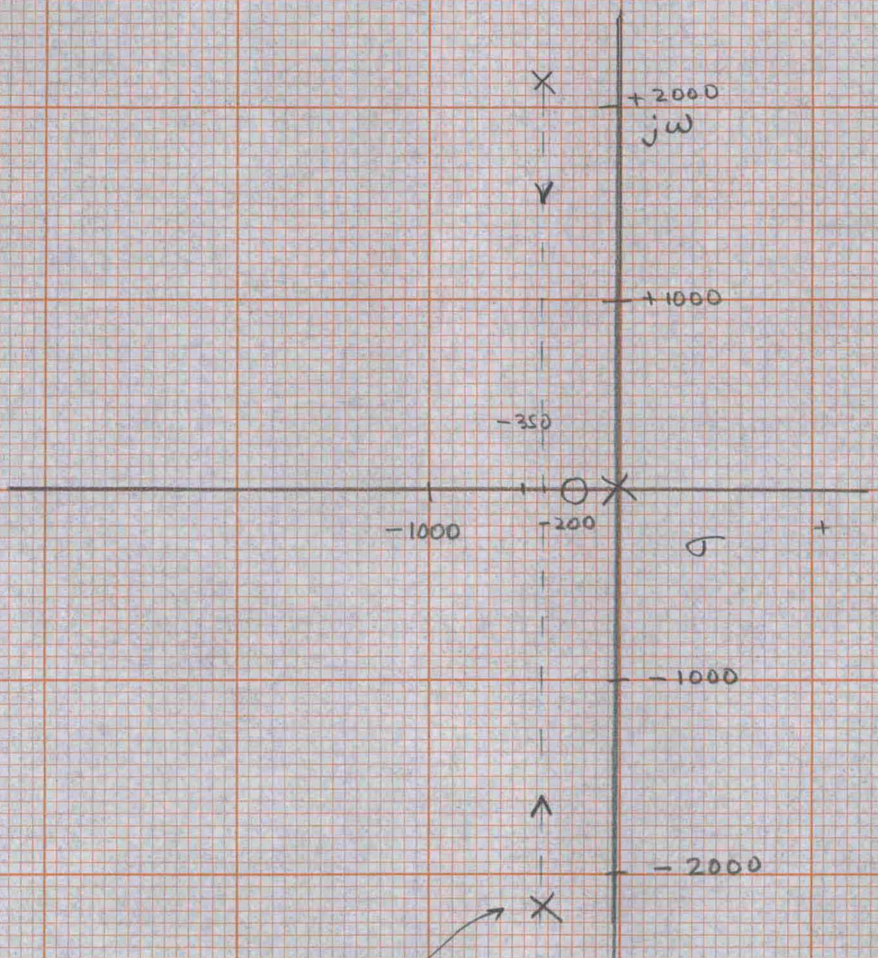
where $\psi \triangleq \tan^{-1}\frac{\beta}{a_0-\alpha} - \tan^{-1}\frac{\beta}{-\alpha}$

$\beta_0^2 \triangleq \alpha^2+\beta^2$

So, after some substitutions:

$$v_{out}(t) \cong 9.95\times10^2 + 10.05\times10^3\, e^{-500t}\sin(2.21\times10^3 t - .1) \longleftarrow$$

As can be seen from the graph of $V_{out}(t)$ as a function of time in FIGURE 5, this is highly oscillatory and not satisfactory. An examination of the pole-zero diagram explains why:



These complex poles must be moved in toward the real axis.

EXAMINE THE FORM OF $V_{out}(t)$ when these poles have moved to the real axis:

$$V_{out}(s) = \frac{K(s+\gamma)}{s(s+\beta)(s+\eta)}$$

β & η real

$$v_{out}(t) = K\left[\frac{\gamma}{\beta\eta} + \frac{\gamma-\beta}{\beta(\beta-\eta)}e^{-\beta t} + \frac{\gamma-\eta}{\eta(\eta-\beta)}e^{-\eta t}\right]$$

no sine terms in this expression – no oscillation.

AN OPTIMUM RESPONSE TIME CAN BE FOUND BY ALTERING THE TIME CONSTANTS OF THE WATT CONVERTER OR THE POWER CONTROLLER OR BOTH. IN ANY CASE IT APPEARS THAT THIS TIME SHOULD BE ON THE ORDER OF 25 msec OR LESS.

FIGURE 5

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