

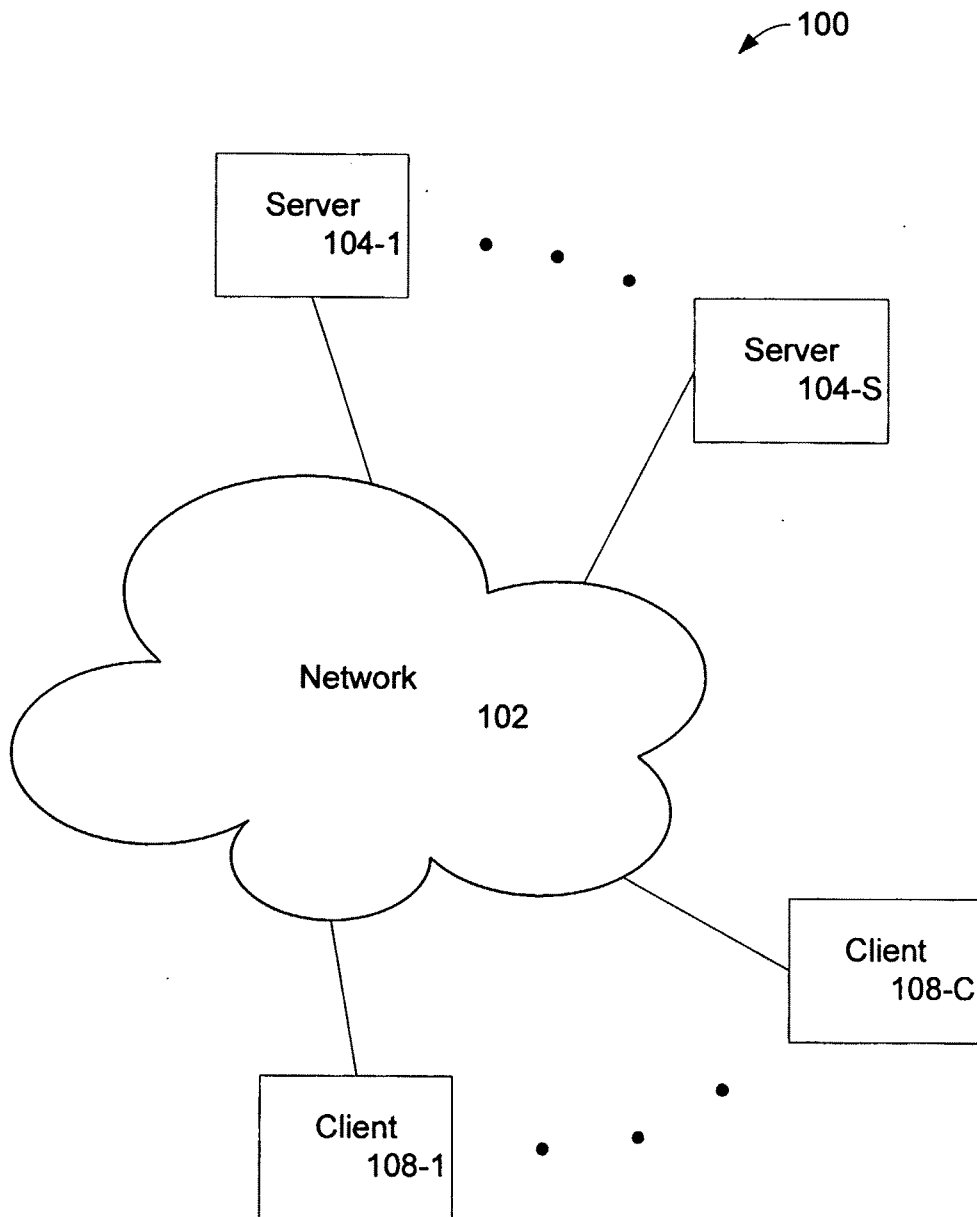


FIG. 1

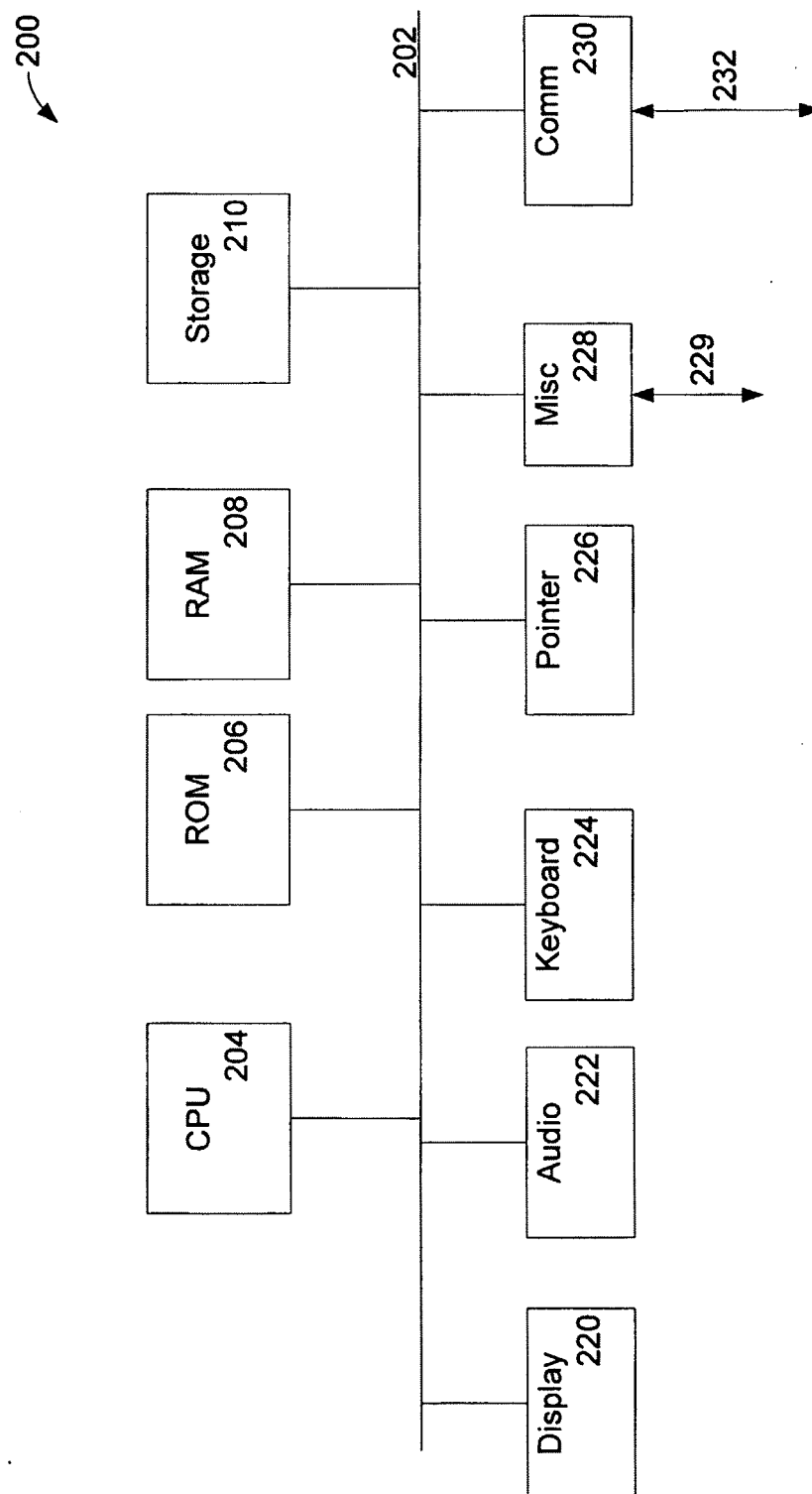


FIG. 2

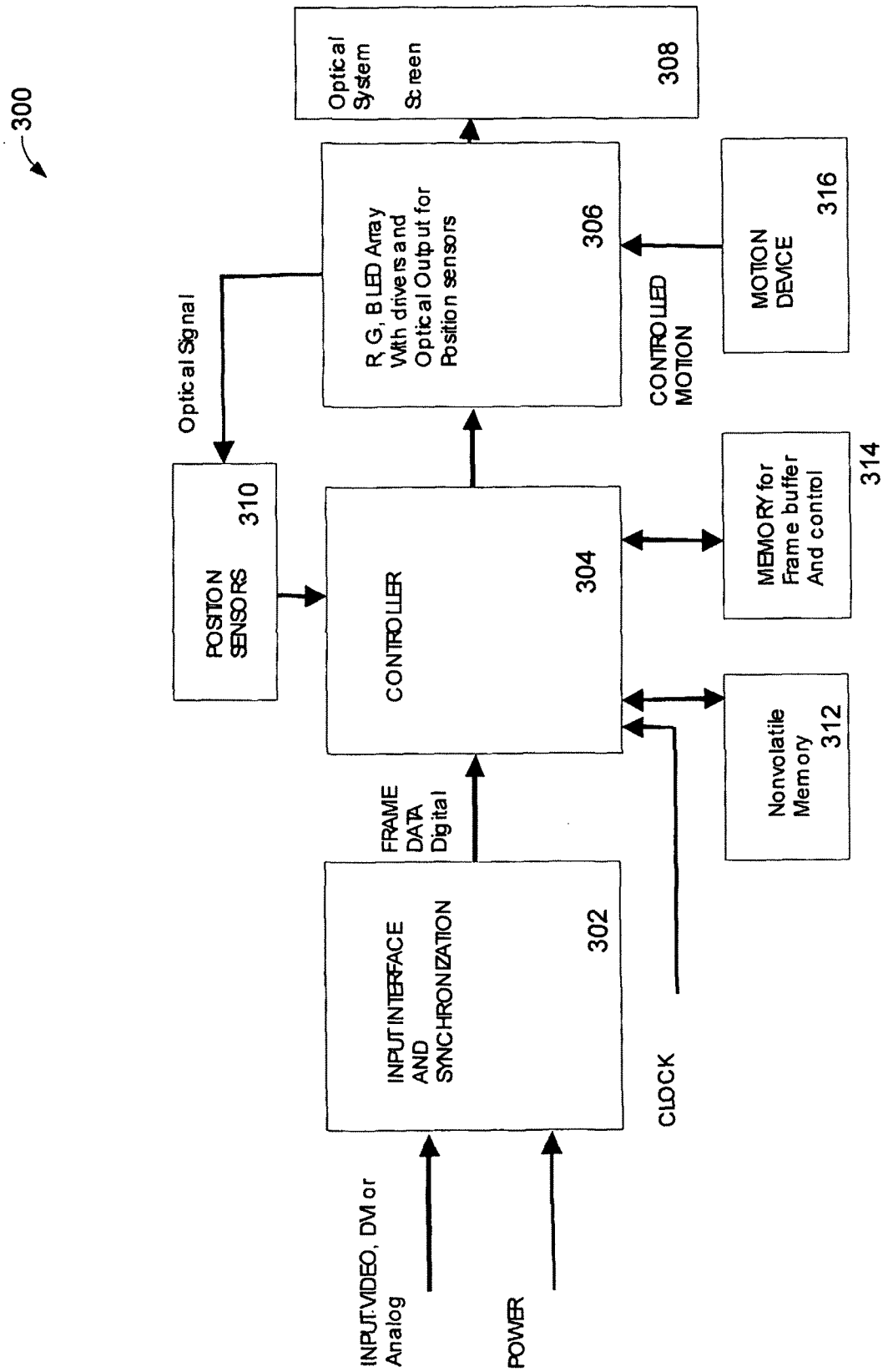


FIG. 3

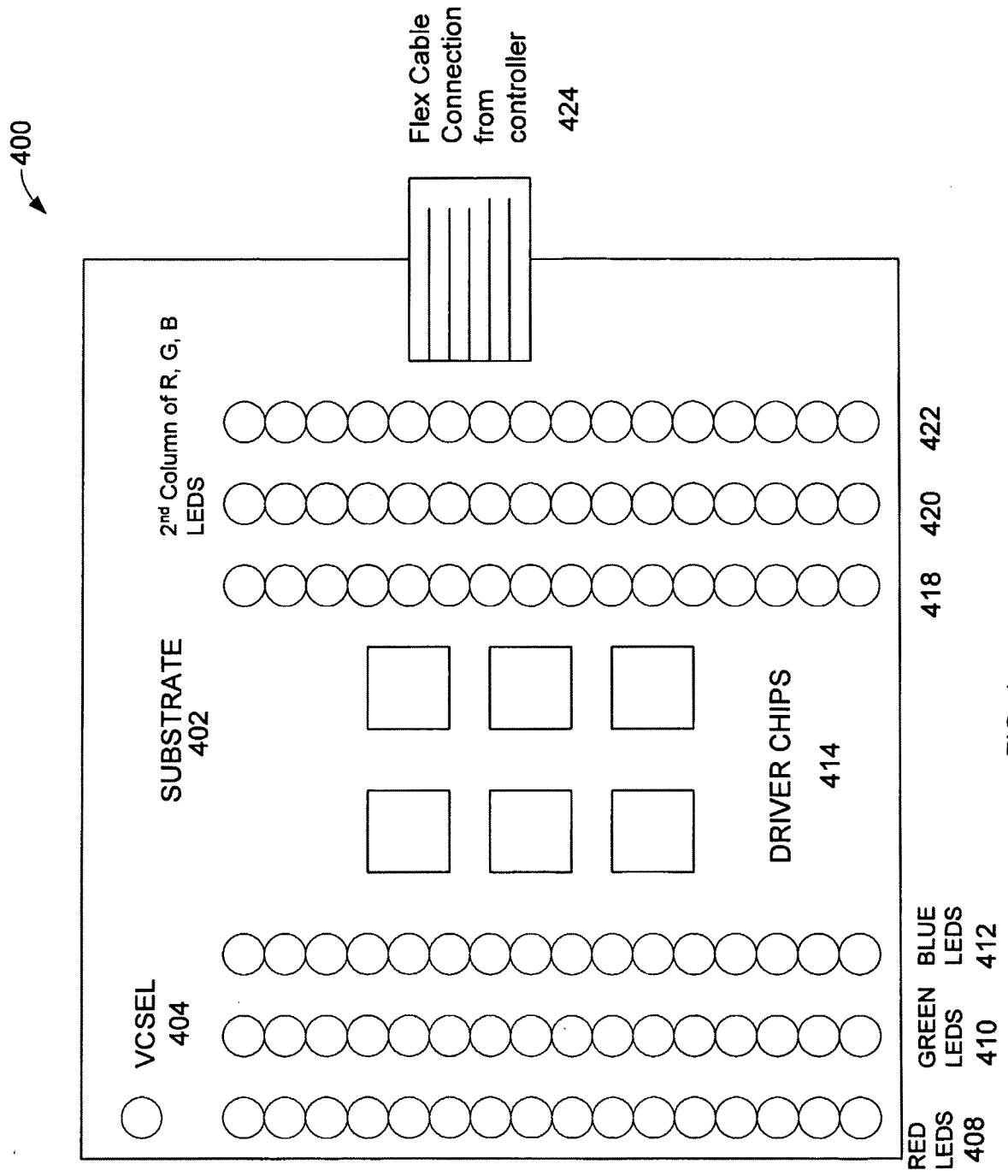


FIG. 4

500
509

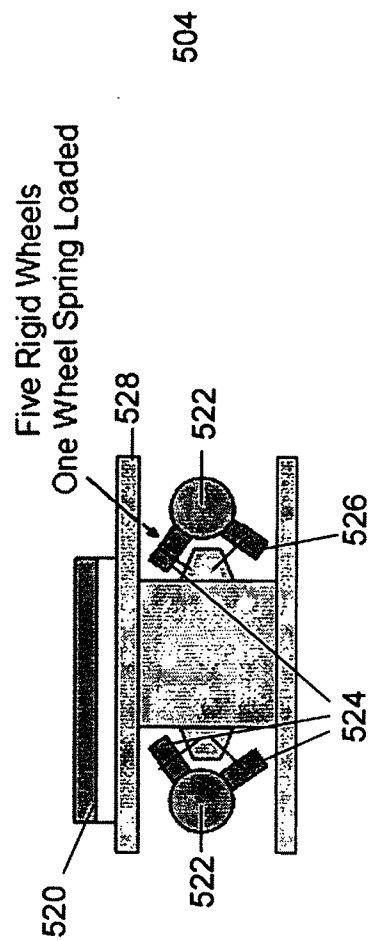
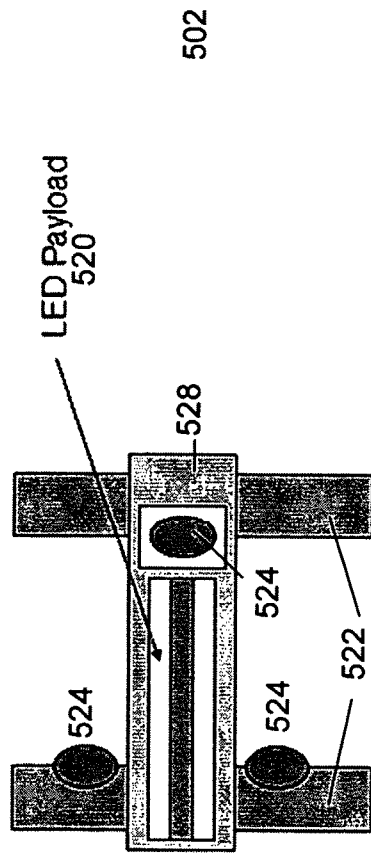


FIG. 5

600

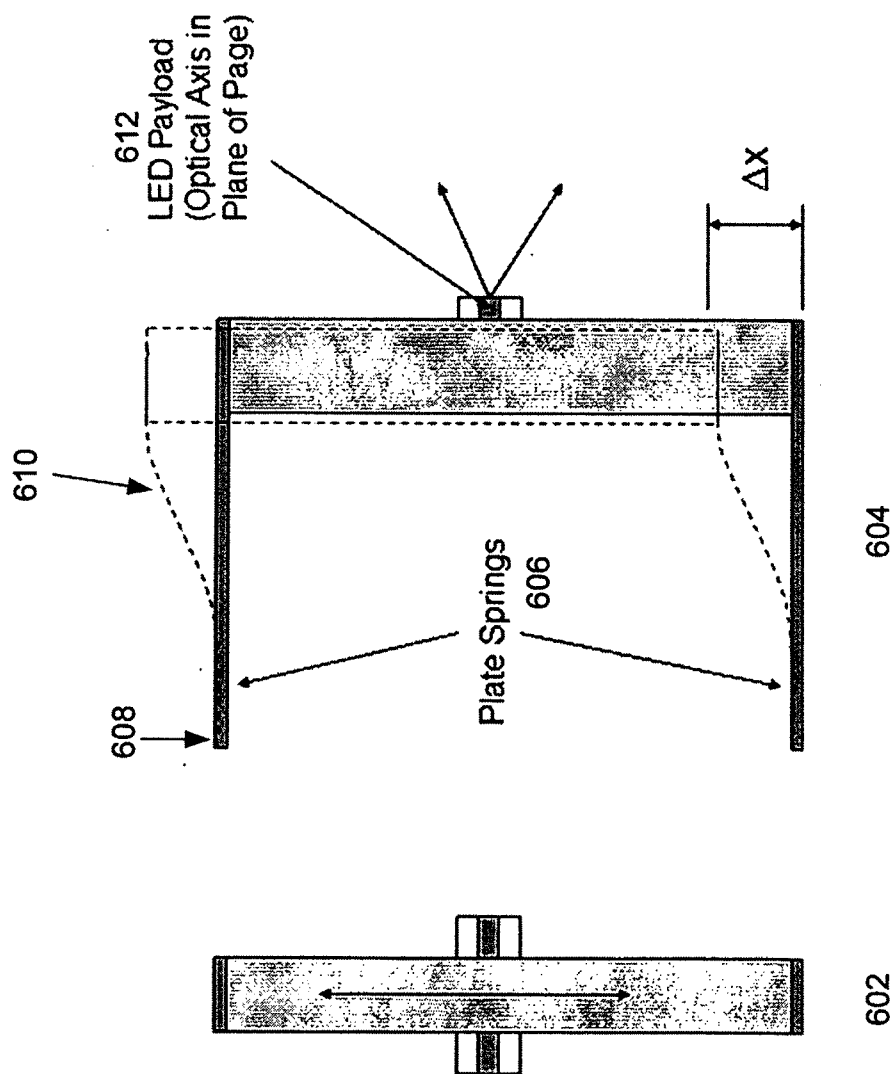


FIG. 6

700

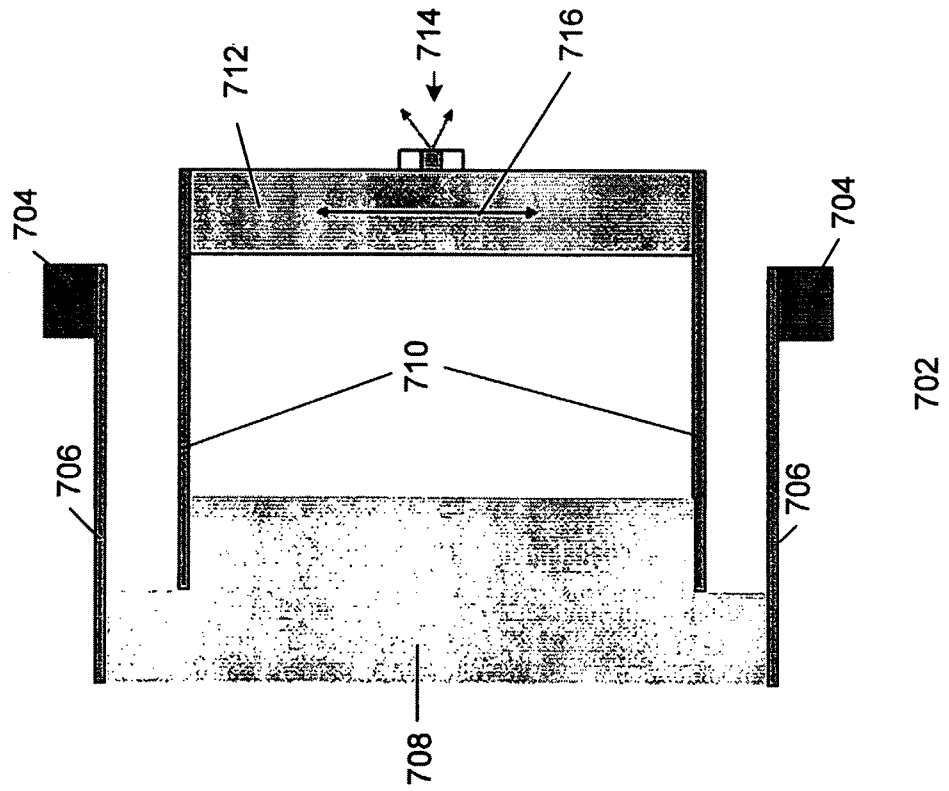


FIG. 7

800

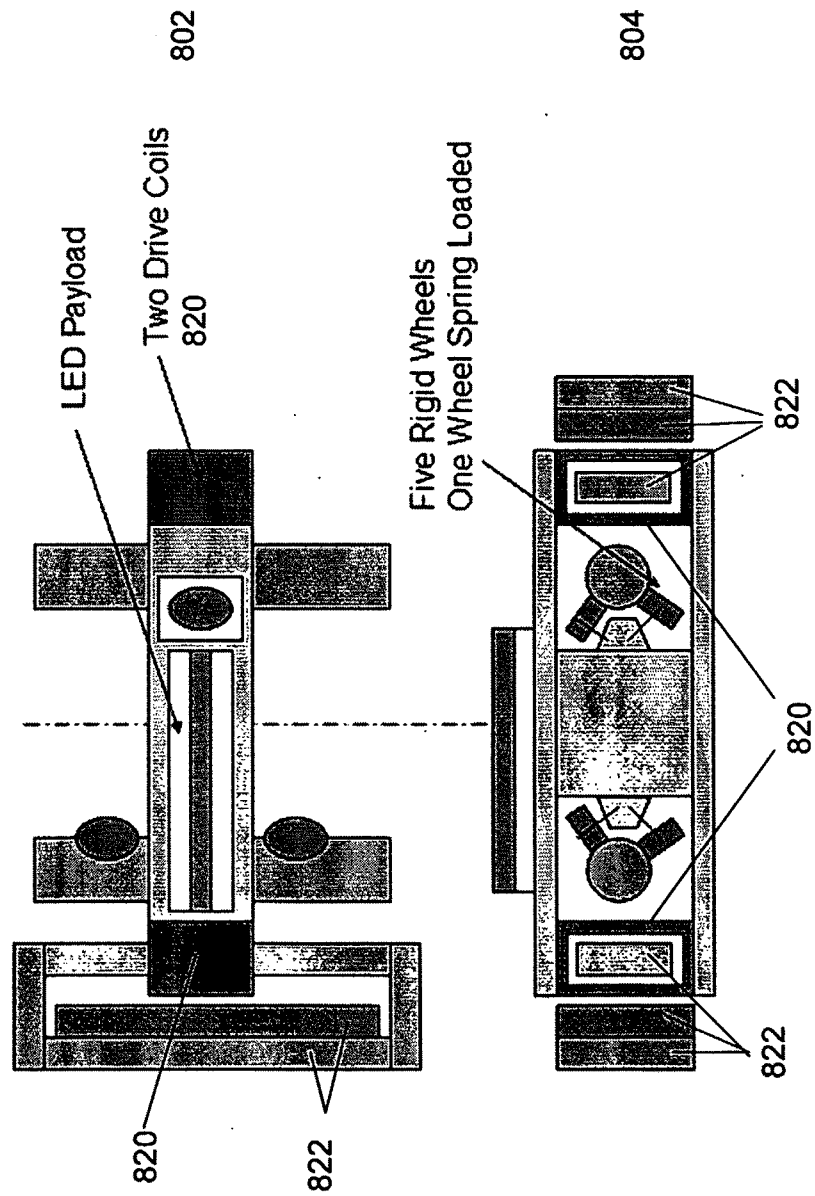


FIG. 8

900

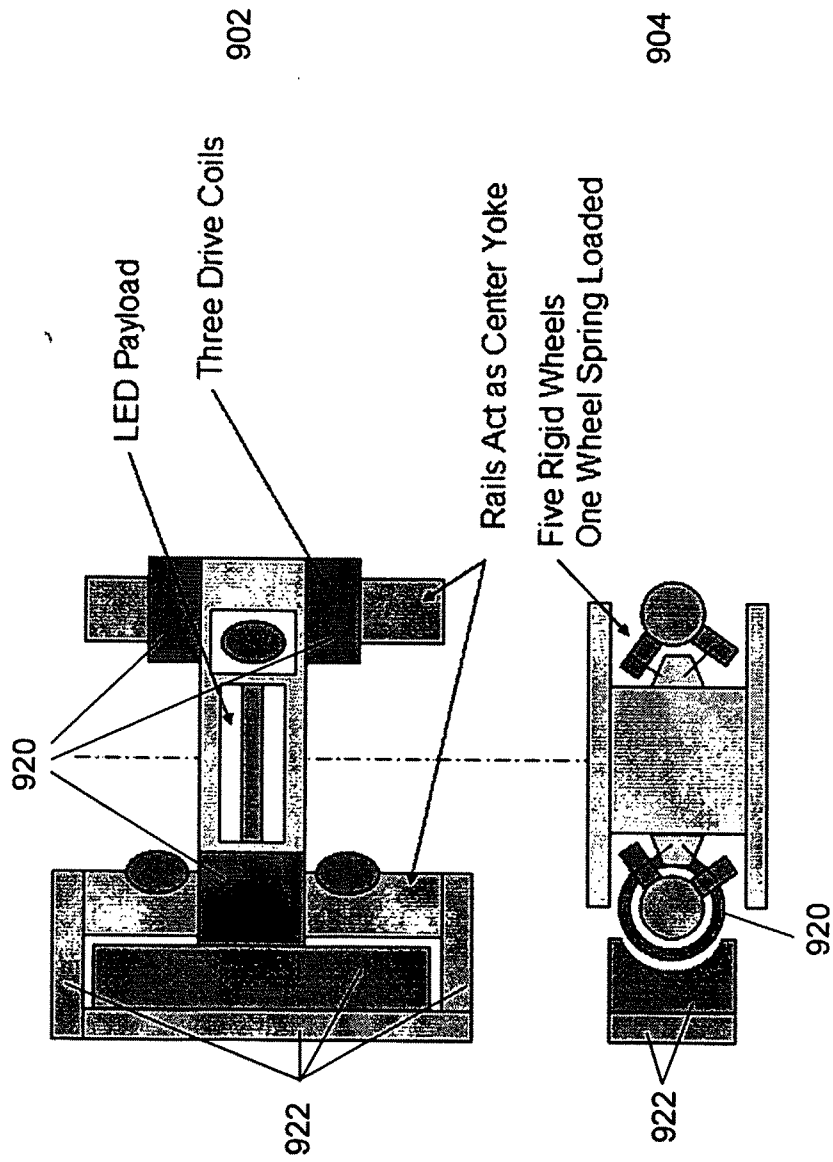


FIG. 9

1000

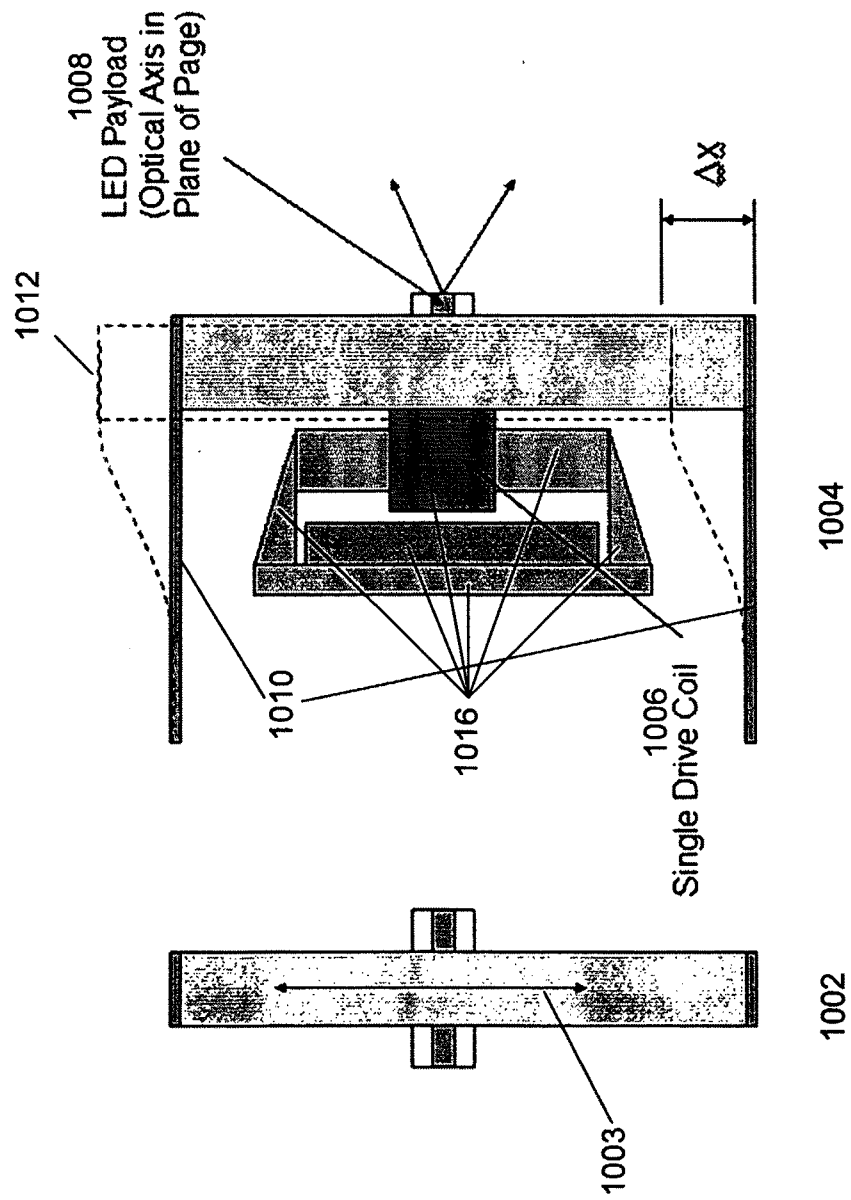


FIG. 10

1100

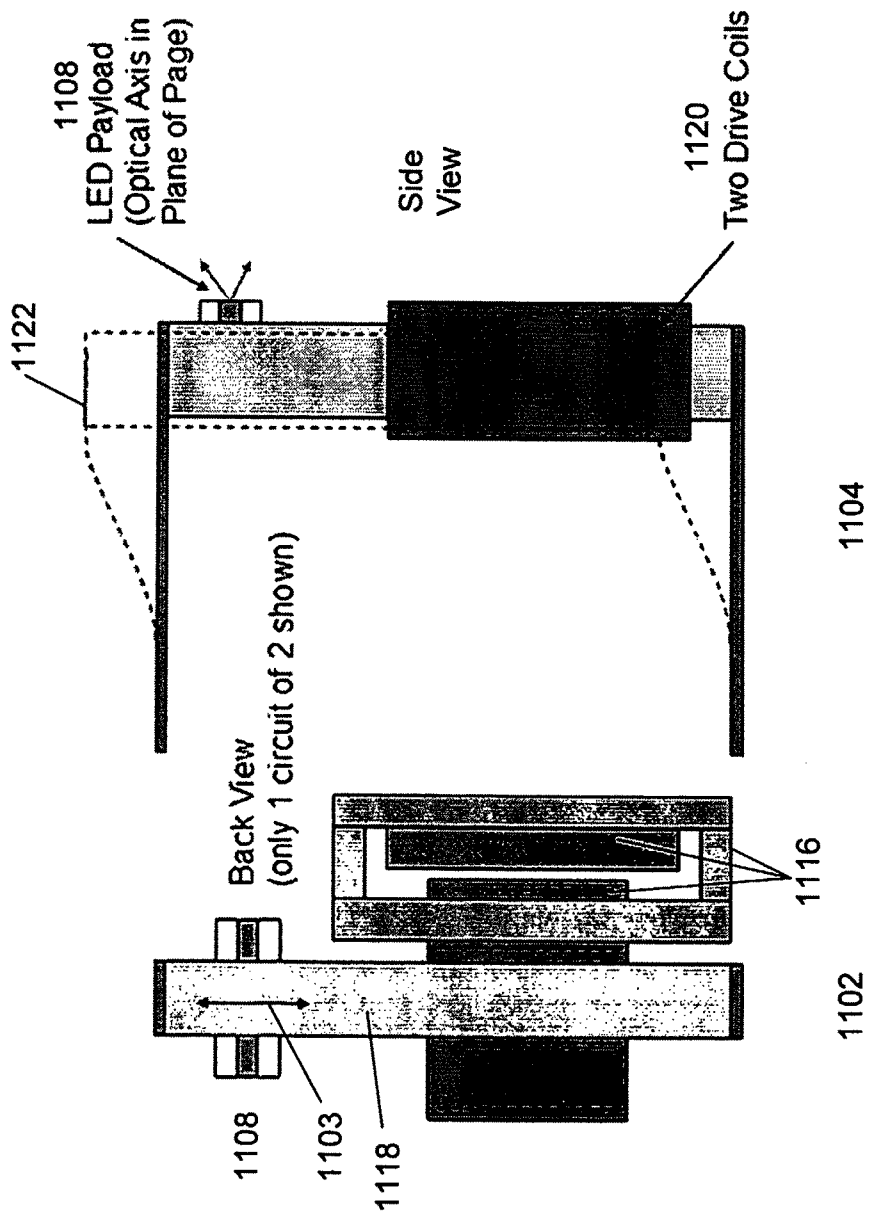


FIG. 11

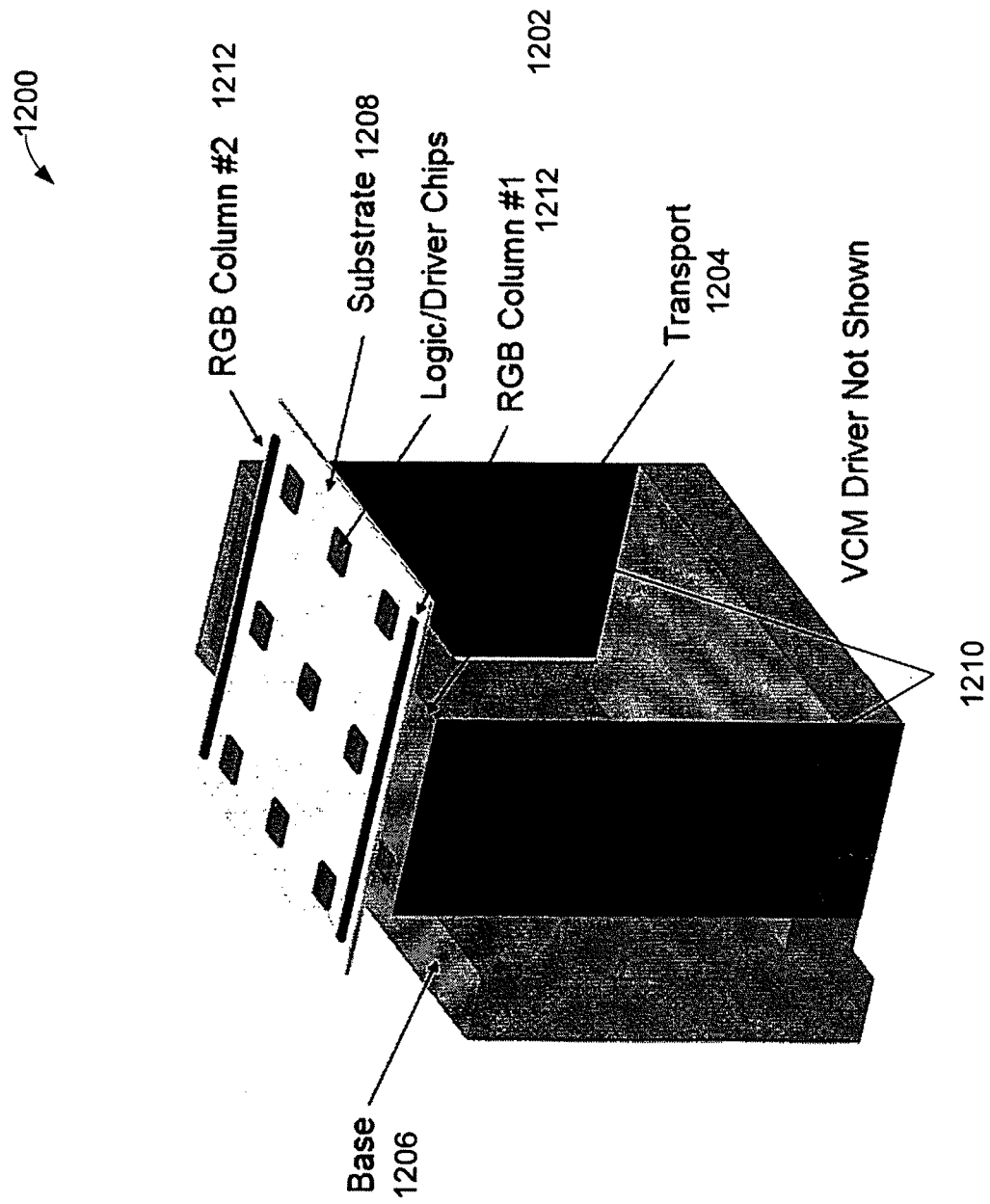
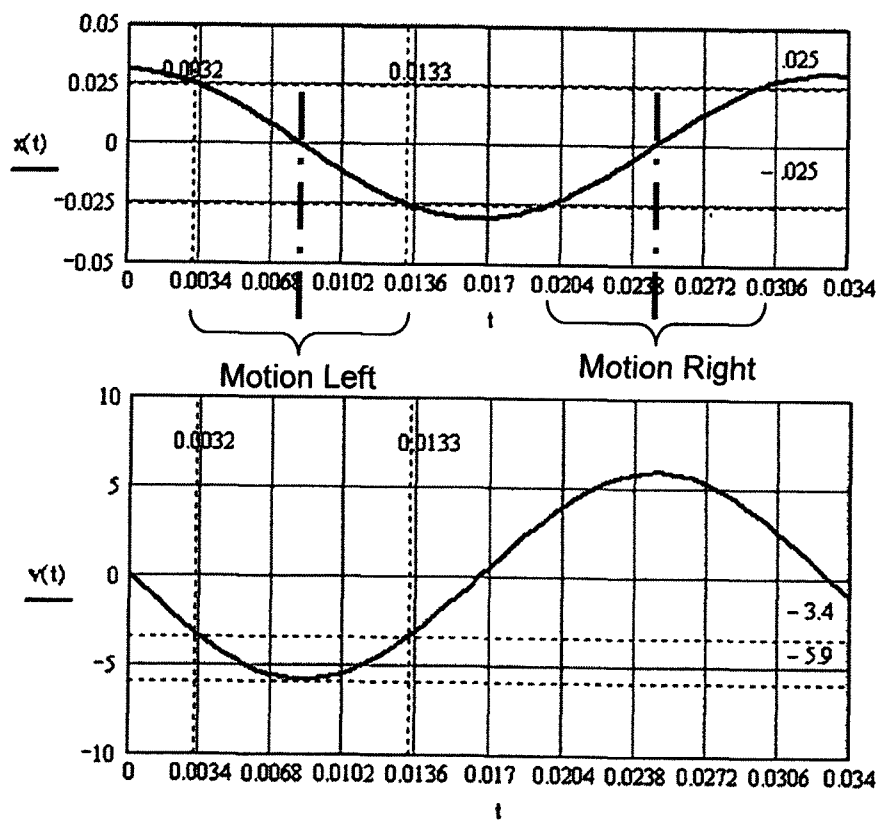


FIG. 12

1300



1302

1304

FIG. 13

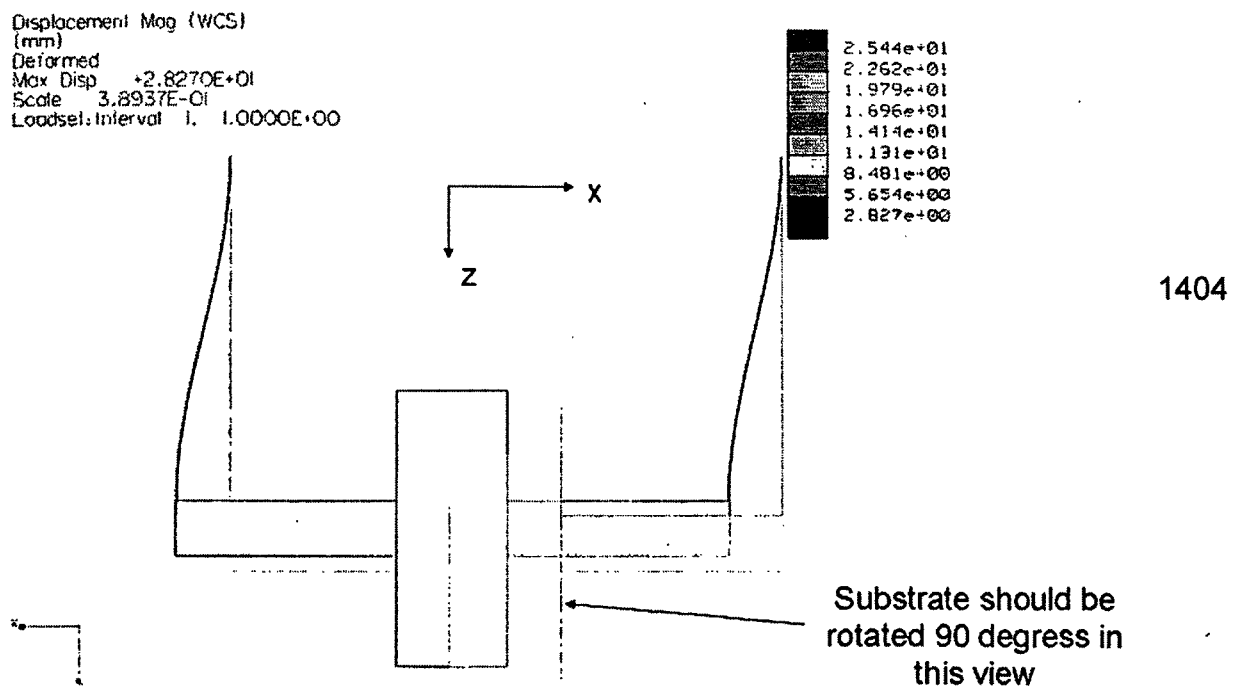
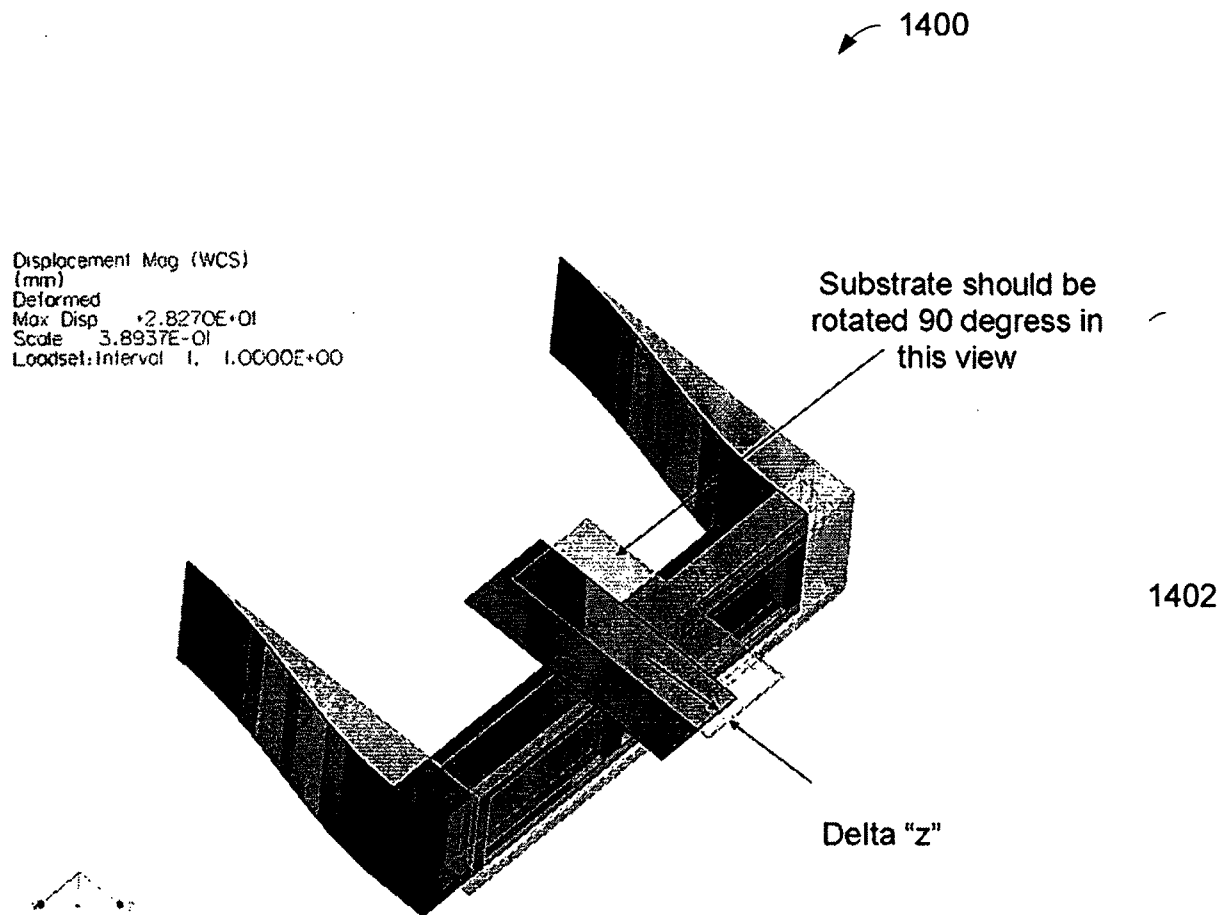
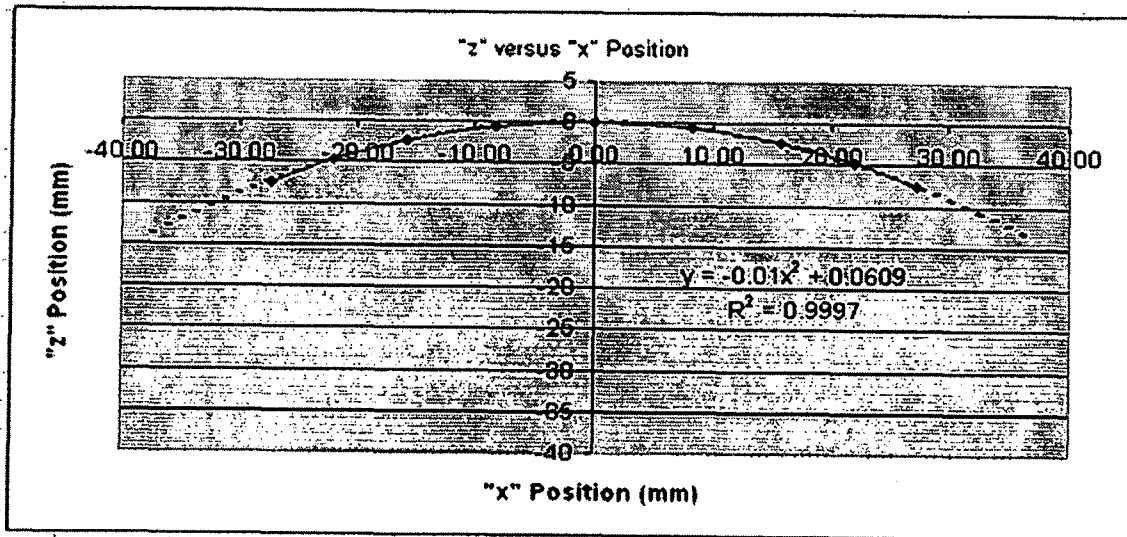
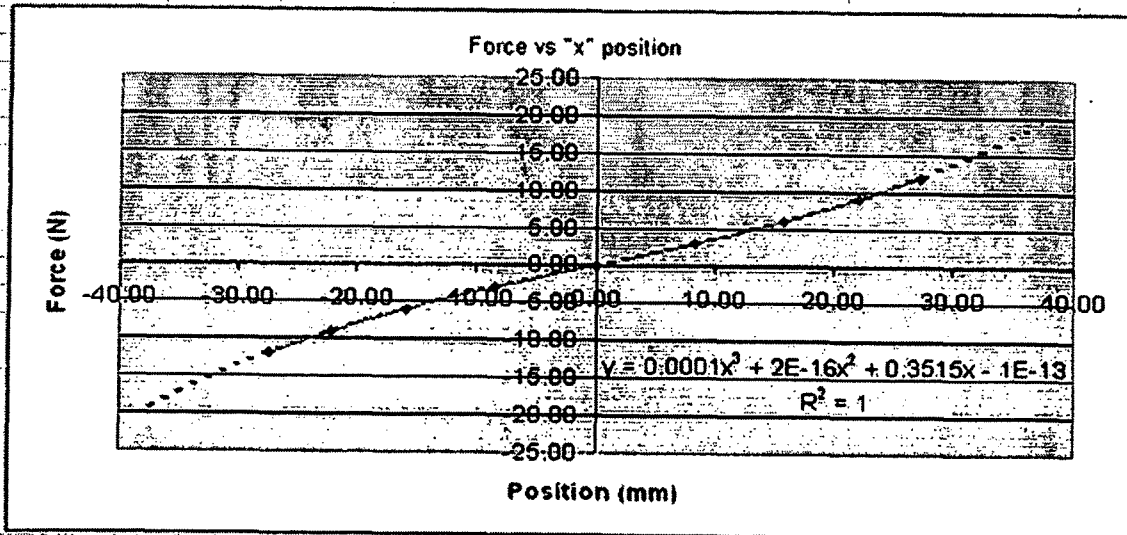


FIG. 14

↖ 1500



1502



1504

FIG. 15

1600

+

"Flexured LED Actuator"

$m = .001$ $k = 1000$

- Suspension -

Width $B := .030$ (m)

Thickness $TE := .008$ (in.)

$TM := TE \cdot .0254$

Length $L := .050$ (m)

Modulus $E := 1.813 \cdot 10^{11}$ (N/M²)

$$\text{Stiffness } K_s := \frac{2 \cdot E \cdot B \cdot TM^3 \cdot 1.0}{L^3 \cdot .95}$$

note: Factor 1.0 is for damping tape Factor .95 is for beam to plate correction

—————>

Stiffness

$K_s = 769.6$

(N/M)

$MM = 0.0212$ (Kg)

$K_f := 1.0$ (N/A)

$PK := 35$ (dB)

$$\delta := \frac{1}{2 \cdot \left[10^{\left(\frac{PK}{20} \right)} \right]}$$

$$Cc := 2 \cdot MM \cdot \sqrt{\frac{K_s}{MM}}$$

Available Current

$I_{max} := 0.3$

(Amps)

$\delta = 0.00889$

$C_d := \delta \cdot Cc$

Damping Coefficient

$C_d = 0.072$

(Kg/s)

$$NF := \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{K_s}{MM}}$$

Natural Frequency

$NF = 30.32$

(Hz)

$NF \cdot 2 \cdot \pi = 190.5$

1602

FIG. 16

↖ 1700

$$G(s) := \frac{K_f}{MM \cdot s^2 + C_d \cdot s + K_s}$$

$$\frac{K_f}{K_s} = 1.301 \times 10^{-3}$$

$$|G(0.2 \cdot \pi \cdot j)| \cdot 1000 = 1.3 \quad (\text{mm/A})$$

$$|G(NF \cdot 2 \cdot \pi \cdot j)| \cdot 1000 = 73.2 \quad (\text{mm/A})$$

$$\text{Acc} := I_{\max} \cdot \frac{K_f}{(9.8)MM} \quad \text{Acc} = 1.45 \quad (\text{G's}) \quad \text{Acc} \cdot 9.8 = 14.17 \quad (\text{m/s}^2)$$

$$\text{Motion @NF} \quad \text{Motion} := |G(NF \cdot 2 \cdot \pi \cdot j)| \cdot I_{\max} \quad \text{Motion} = 0.022 \quad (\text{m})$$

$$\text{Motion}_E := \frac{\text{Motion}}{.0254} \quad \text{Motion}_E = 0.86 \quad (\text{in})$$

$$\frac{K_f}{[MM \cdot (200 \cdot 2 \cdot \pi)^2]} \cdot 1000 = 0.03 \quad |G(0.2 \cdot \pi \cdot j)| \cdot I_{\max} = 3.903 \times 10^{-4}$$

BODE CALCULATIONS

$$n := 10000 \quad i := 1..n$$

Min frequency
Max frequency

$$\min := .1$$

$$\max := 100$$

$$r := \ln\left(\left|\frac{\max}{\min}\right|\right)$$

$$f_i := \min \cdot e^{i \cdot \frac{r}{n}}$$

$$s_i := 2 \cdot \pi \cdot f_i \cdot j$$

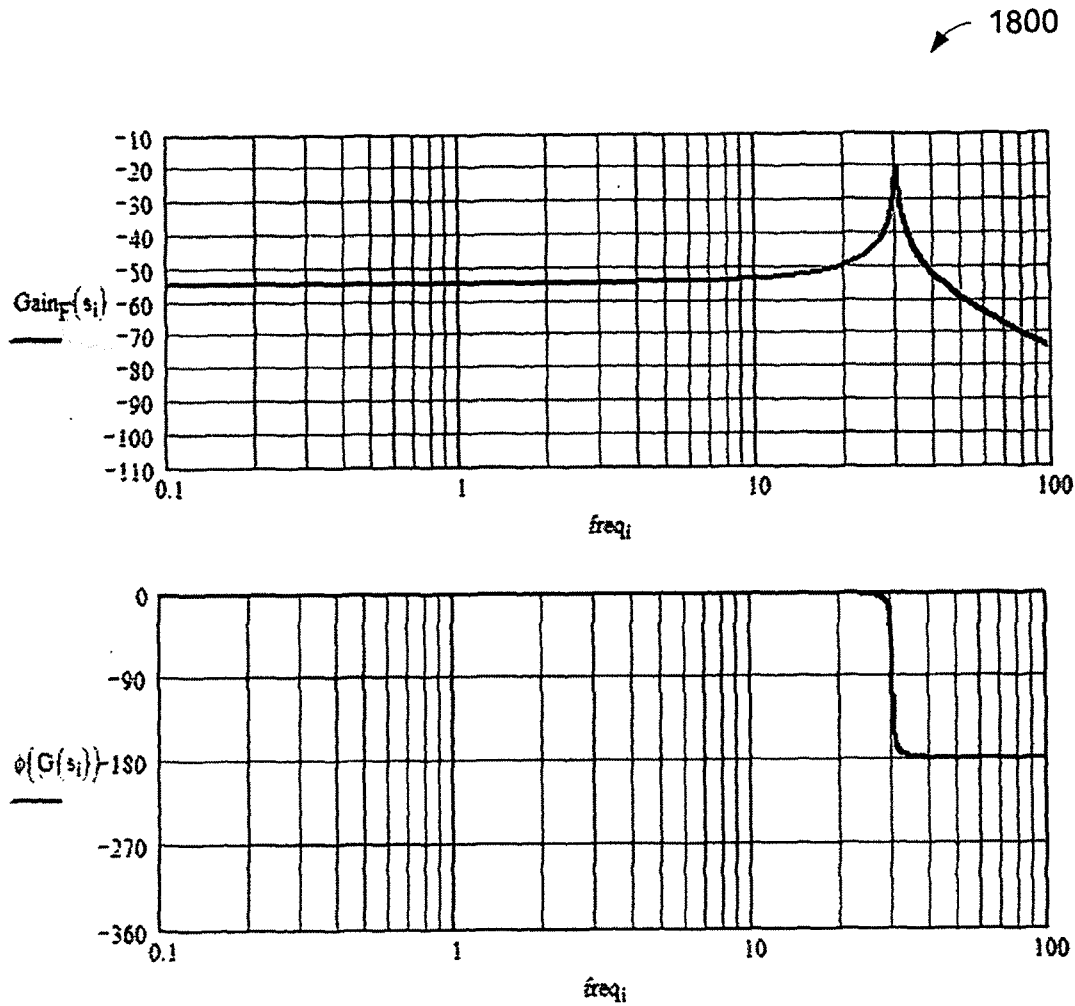
$$\text{freq}_i := \left| \frac{s_i}{2 \cdot \pi} \right|$$

$$\text{Gain}_F(s) := 20 \cdot \log(|G(s)|)$$

$$\phi(\theta) \equiv \text{angle}(\text{Re}(\theta), \text{Im}(\theta)) \cdot \left(\frac{180}{\pi}\right) - 360$$

1702

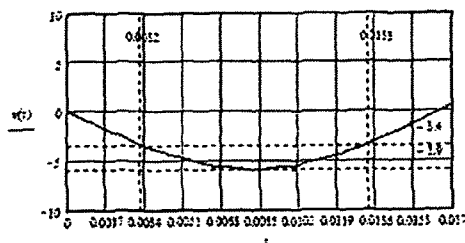
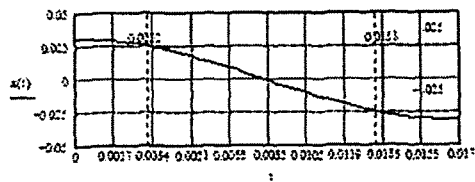
FIG. 17



$$f = 2\pi f \quad (\text{Hz}) \quad \omega = 2\pi f \quad \tau = 0.0001 \text{ s}$$

$$A = \text{Motion} \quad \phi_1 = 90 \quad p_1 = \left(\frac{\phi_1}{360.320} \right)$$

$$x(t) = A \sin(\omega t - p_1) \quad v(t) = A \omega \cos(\omega t - p_1)$$



SUMMARY OF PARAMETERS

- Suspension -	Width	B = 0.03 (m)
	Thickness	TE = 0.005 (m)
	Length	L = 0.85 (m)
	Stiffness	K _s = 755.5 (N/m)
- Mass -	MOI	0.021 (Kg)
- Mech Natural Frequency -	NF = 30 (Hz)	PK = 35 (dB)
- Scan Frequency -	2NF = 61 (Hz)	
- Force Constant -	K _f = 1.4 (N/A)	
- Current -	I _{max} = 0.3 (Amps)	
- Motion @ Resonance -	Motion ₀ = 0.031 (m-peak)	2Motion ₀ = 0.061 (m-pp)
	Motion ₂ = 1.2 (m-peak)	2Motion ₂ = 2.4 (m-pp)
- Velocity Cutoff Criteria -	Vel _{min} = 55 (degrees from each end of 180)	
	Stroke _{min} = 0.05 (m-pp)	
	Stroke _{max} = 1.552 (m-pp)	
- Velocity Minimum -	v(T _{1cut}) = -3.4 (m/s)	
- Velocity Maximum -	v(0.5 T _{1cut}) = -1.8 (m/s)	