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Dave. S

PRELIMINARY DESCRIPTIONS

OF AN ANIMATION DEVICE

(COPY)

TABLE OF CONTENTS

INTRODUCTION

This invention relates to an electronic device for the production, animation, and display of pictures (drawings) and visual symbols.

It is an object of this invention to provide an apparatus for use by artists, film directors, or producers which will a) generate and display images and visual symbols, and B) allow, by means of proper controls, for the animation (movement) of these images. It is also an object of the invention to provide a means by which the actions of the images and symbols may be recorded in part or in whole by either film or magnetic tape or other suitable recording means. It is also an object of this invention that once the desired image information has been properly stored in the device by means of photographic film, or other suitable memory storage medium, that the generation of the picture on a display device is automatic.

Another object of the invention is to display the imahes being generated in such a way as to allow suitable rapport between an operator and the device (feedback) and simultaneously (in parallel) to display in such a manner within the device as to allow for any image conversion techniques which may be employed for the superposition of characters or parts of images and backgrounds, and for the final recording of the output images. It is also an object of this invention to give to the operator a means by which he may control (by manipulation of various control potentiometers) the movement and/or distortion and existance of visual images such as characters, objects, props, backgrounds, colors, or special effects in a manner which is consistent with human control capabilities.

A more specific object of the invention is to provide a fast, lower cost means of picture animation with such a broad range of control and automaticity that the artistic endeavors are limited only by the operator's imagination.

It is also an object of this invention that certain proportions of the apparatus may be used for the immediate generation of visual symbols in a suitable or significant array or position as to convey fraphic meaning to insoming intelligence which requires immediate display and dissemination as may be required in military control centers, or in television broadcasting, or in advertising displays, or is any situation where immediate display of timely, visual information is desirable.

It is another object of this invention that control need not be limited to the physical manipulation of the controls, but that control may be effected by electronic signals of a source other that the ones generated by control manipulation by an operator.

It is also an# object of this invention that information (concerning pre-arranged classes of visual objects or symbols of rather complex nature) may be sent via suitable communication means between stations which have these devices having the advantage of exceedingly low, time-bandwidth product requirements in the communication channel. (A unique feature of this device is that redundant information which must be necessarily produced to adhere to the requirements of the human vision eye (ie. persistance of vision) is generated automatically by the device and only information regarding gross, low-frequency changes in the postion or status of the images is reauired.) It is also an object of the invention that it be used in generating and displaying information concerning status and/or postion of certain objects with relation to fixed referencesas may be ###### needed in conjuction with navigational aids (as showing satelite or aircraft status or position) or for the generation of up-to-the-minute weather maps.

Another object of this invention is that it be used in conjunction with computers for input and putput purposes, where certain functions may be programmed with visual symbols which may be interpreted by both operator and computer, and output may be in terms of meaningful visual symbols, easily and quickly interpreted by human operators.

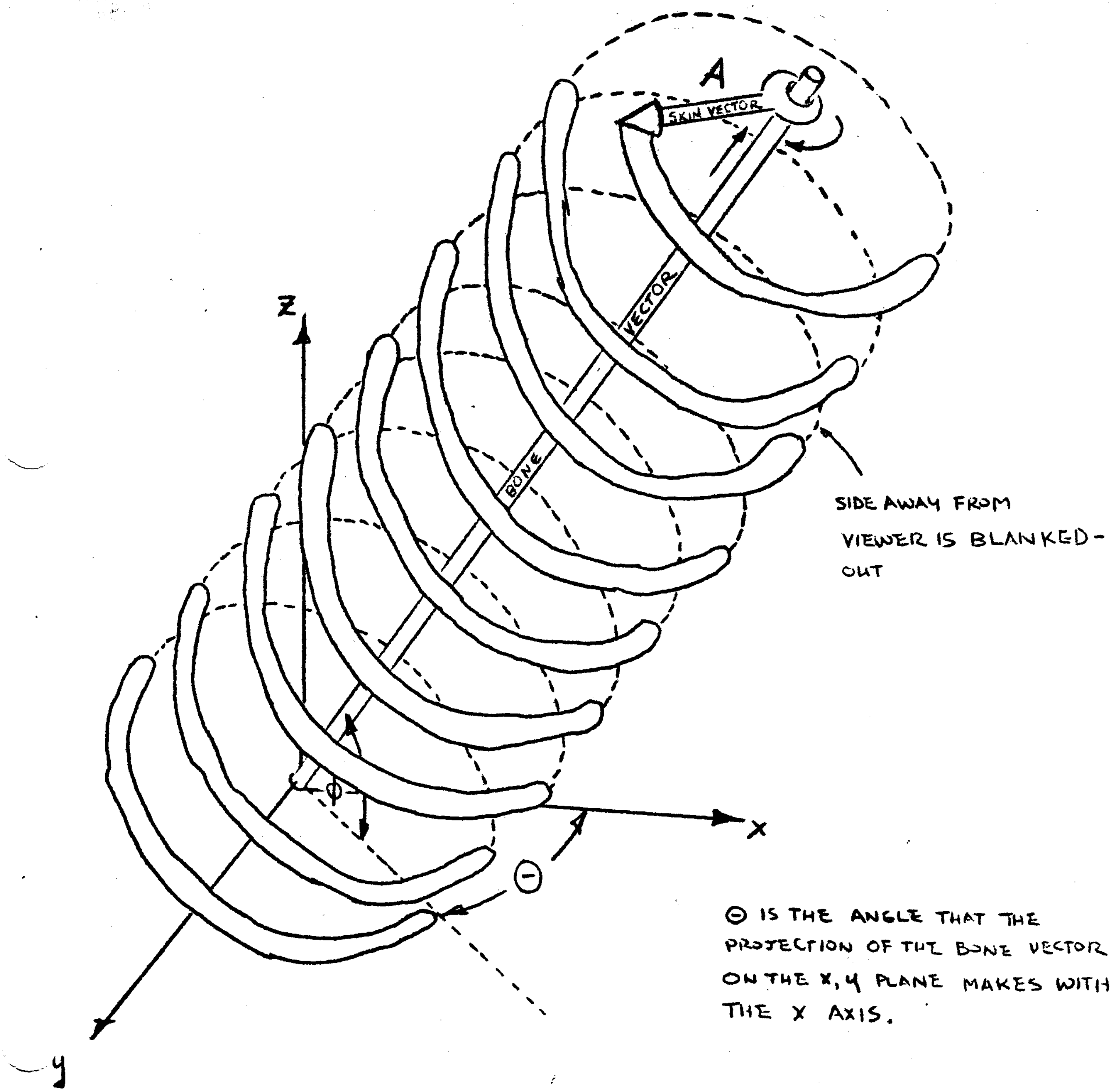
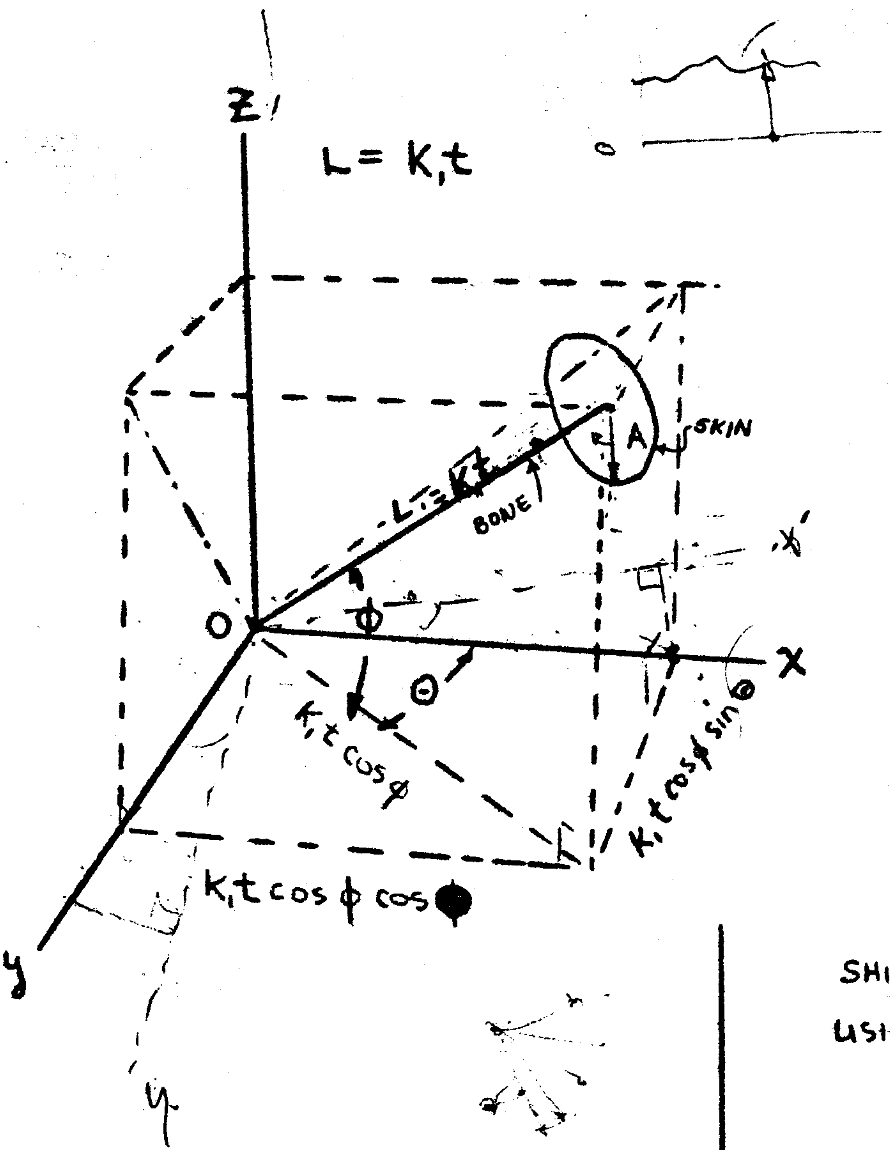
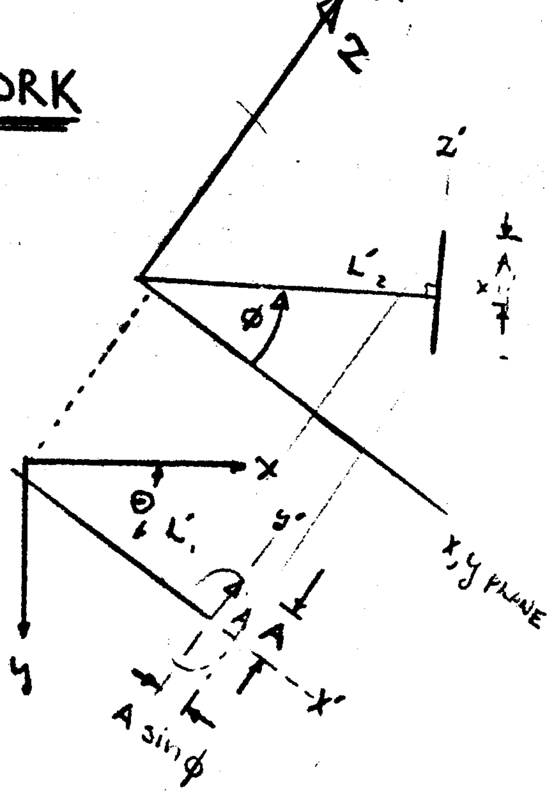

A
SKIN VECTOR
BONE VECTOR
Z
X
Y
φ
Θ
SIDE AWAY FROM VIEWER IS BLANKED-OUT
Θ IS THE ANGLE THAT THE PROJECTION OF THE BONE VECTOR ON THE X, Y PLANE MAKES WITH THE X AXIS.

Fig 1

ANALYTICAL GEOMETRY OF SKIN NETWORK





$$x' = A\sin\phi\cos k_2 t + L'_1$$
$$y' = A\sin k_2 t + 0$$
$$z' = A\cos k_2 t + 0$$
$$x'y' = L'_2$$

SHIFTING (ROTATING) AXES USING

$$x = x'\cos\theta - y'\sin\theta$$
$$y = x'\sin\theta + y'\cos\theta$$
$$z = z'\cos\phi$$

[f(t)]

COMBINING

$$x = K_1 t\cos\theta\cos\phi + A\cos\theta\sin\phi\cos k_2 t - A\sin\theta\sin k_2 t$$

$$y = K_1 t\sin\theta\cos\phi + A\sin\theta\sin\phi\cos k_2 t + A\cos\theta\sin k_2 t$$

$$z = K_1 t\sin\phi + A\cos\phi\cos k_2 t$$

FIG. 2

GENERAL DESCRIPTION

In general, the device consists of a means of automatically presenting to the x, y plates and the z (or brightness control grid) axis of an oscilloscope-type electronic display, simultaneous continuous signals representing the x and y components of the motions of the beam which cause the beam of the oscilloscope to draw a 2-dimensional projection of 2 or 3-dimensional visual images in representative fashion on the tube face; and a means of controling the position, interrelation, color, artistic texture and brightness of the visual images in whole and/or in part by means of manual or automatically generated electronic control inputs.

The images to be generated and controlled may be thought of as having, or being composed of, "bones" and "skin". A "bone" in this context is a spacial vector, a line in three dimensional space which has a determined length, a determined starting point, and a determined direction, a direction which may be described by the angles θ and ∅ which the bone or vector makes with the familiar standard xz and xy planes respectively of 3-dimensional geometry. (FIG 2). (θ IS THE ANGLE THAT THE PROJECTION OF THE VECTOR ON THE XY PLANE MAKES WITH THE X AXIS) On the other hand, the "skin" of the image as herein described, may be thought of as the thickness or shape (3-dimensional or otherwise) of the visual image, and may be described as the locus of all points described by the end or tip of a variable-length skin vector which eminates from the bone and terminates at the surface of the skin of the object, as it (the vector) rotates or spins orthagonally around the bone as its root travels along the length of the bone from one end to the other. For clarity fig. 1 shows this representation.

The bone vectors and skin vectors are generated separately, but synchronously or parallel in time and then added together so as to produce a spacially 3-dimensional electronic representation of the figure, a selected, 2-dimensional projection of which is drawn on the face of the display scope. Combinations of bone and skin vectors representing different parts of the total visual image are generated in a logical sequence (as to be described).

The image drawn on the face of the scope is the 2-dimensional projection (on a selected plane) of the end or tip of the skin vector as it rotates along the bone or merely a projection of the bone itself (if no skin is added). Vectorial time-components of the computed projection (vertical and horizontal) are continuously generated and these positional signals are fed into the x and y channels of the display device to create the image.

Motion of the image is effected by drawing the image in a repetative, sequentially-changing manner, and presenting to the eye a series of "still" pictures, but, if motion be desired, each picture slightly changed from the beginning picture, taking advantage of the familiar persistance of vision.

Motion of the image is effected by moving or changing the position of the bone vecotrs (attitude motion), and/or changing the ~~information input to~~ length of the skin vector ~~length~~ (plastic motion), and/or orthoganality to bone vector and/or by changing the selected projection plane (camera angle motion).

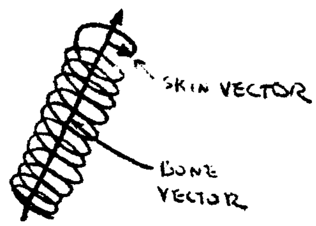
In general, color, textural, and shading of the visual image are effected by proper modulation of the signal presented to the brightness control grid (~~accelerating grid~~) of the display scope thereby modulating the intensity of the beam. Specifically color may be effected by using a color display apparatus (as a color TV receiver) or a combination of scopes using different colored filters, or phosphors, and super-imposing the images by optical means (semi-transparent mirrors).

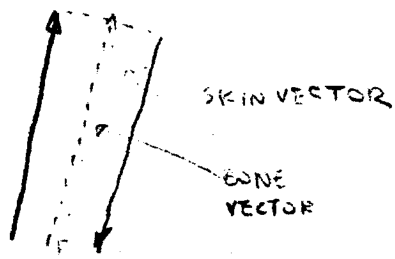
SUMMARY

In blocking out our patent area there are certain basic ideas which, if we could claim as our own, would give us the room we need to work in. The patenting of combinations of components rather than specific circuits would seem to be the answer, for the circuits used are so common that there are many possible circuit designs. PERHAPS WE SHOULD THINK IN TERMS OF THE FLOW AND PROCESSING OF SIGNALS

Some basic ideas to keep in mind however are:

A.* The vector addition of the skin vector to the bone vector.





a. Full Basic Format b. OUT-LINE FORMAT

B. The basic idea of using a scanner output to modulate the length of the skin vector.

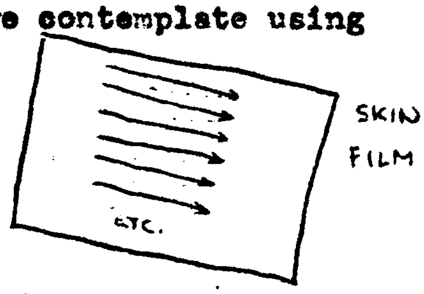
C. The idea that the skin vector is orthagonal (at right angles) or at any particular angle to the bone vector. We may want to change this angle

* SEE GLOSSARY OF FORMATS (p 13)

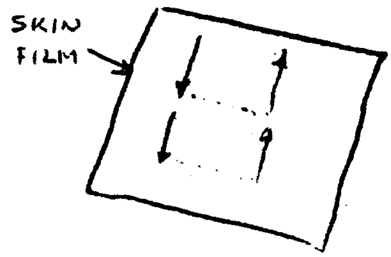
briefly in certain places in order to produce plastic effects in the skin - as in lip or eye motion.

D. The method of generating the skin film of orthagonal information which may be scanned. Right now we are contemplating using the film-density as the storage medium which holds the information of the skin-thickness. There are other ways to hold this information (as in a memory device). Rather than have the information contained in the film density (with density variations from black to white, the information could be encoded in a digital fashion with black and white dots.

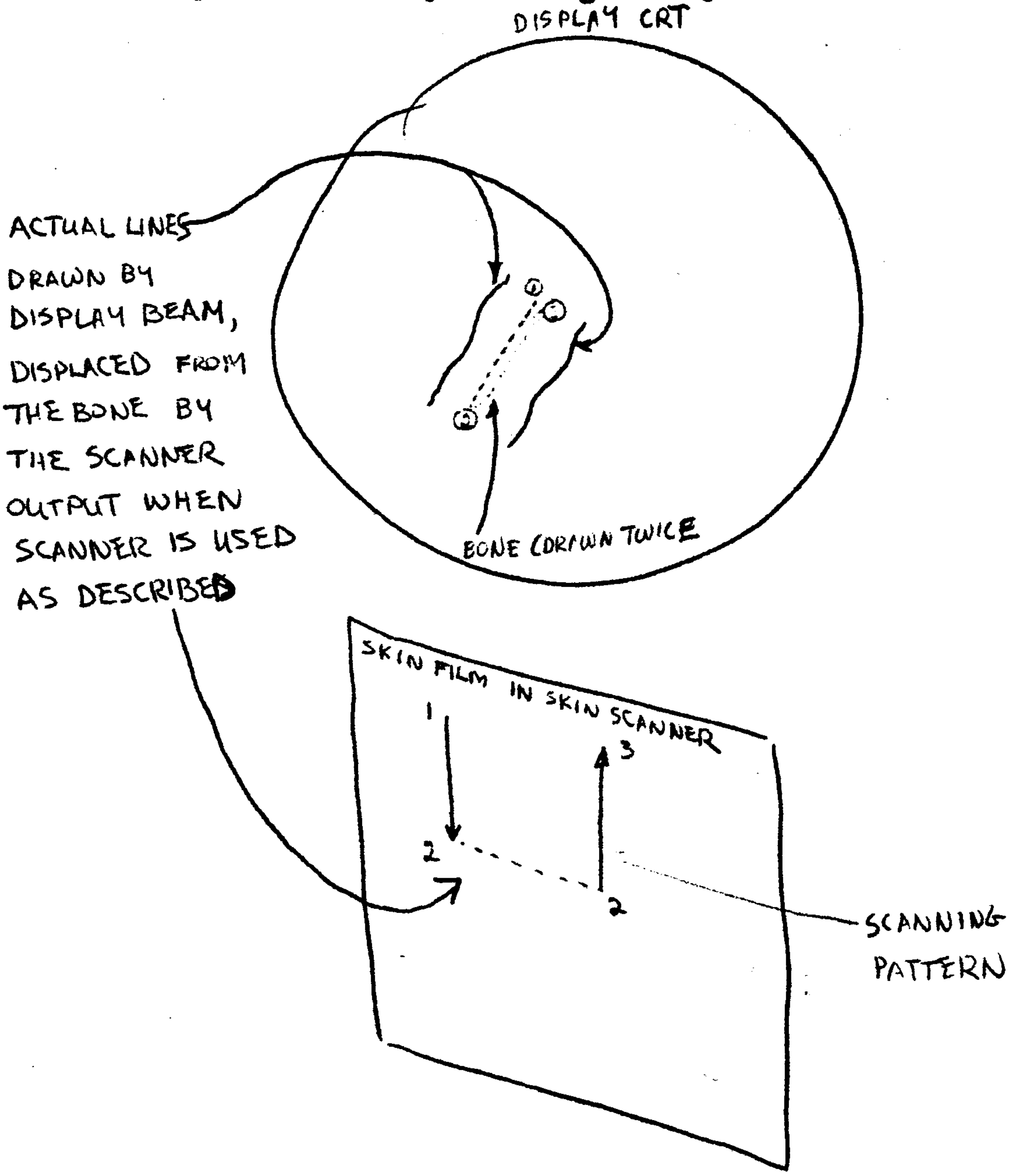
E. We also need leeway in the methods we use for scanning the skin-film. Right now we contemplate using a normal rectangular raster for the full basic format.



But we may want to use a different raster as



where the output of the scanner is used merely to <u>displace</u> the bone vector to one side and/or the other so that we draw a bone twice, thereby drawing on the display only the outlind of the particular object being drawn.



We call this "Outline Format".

F. We also need leeway in circuit design in such a way that we may a) transistorize or b) digitalize the synchronizing and multiplexing techniques.

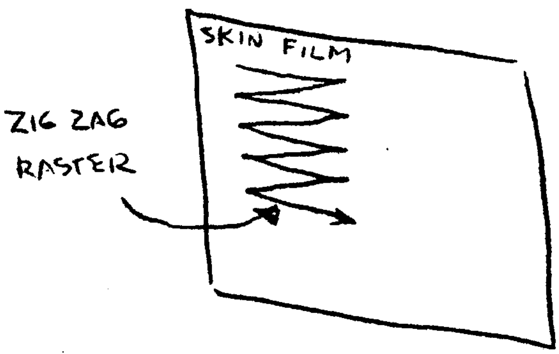
G. We need lots of room in the control end of the device. At present we create electronic inputs to the bone gates by the hand-manipulation of potentiometers. However, we have many ideas for improvements, and as we get more experience with the operation of the device, we will add new circuits and develop new techniques to make control as automatic as possible.

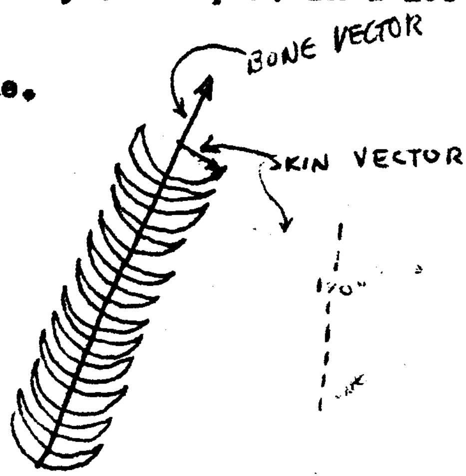
GLOSSARY OF FORMATS

FULL BASIC FORMAT: I want this to be a term which discribes one method (or format) we use to "draw" an object; namely: the simultaneous generation of skin and bone vectors and the vector addition of these and the application of these to the vertical and horizontal channels of a display scope so that the CRT beam sweeps out a projection on the CRT face of the spiraling tip of the sum of the vectors.

OUT-LINE FORMAT: This term is used to describe the object-drawing format which uses the particular scanning pattern and device operation described in "E" of "Summary". Essentially it refers to the technique of drawing outlines of objects or figures.

ANOTHER FORMAT: ZIG ZAG In the zig zag format the skin vector is caused to wobble back and forth, (not spin) in a 180° arc as it travels along the bone.





MORE DETAILED DESCRIPTIONS

MASTER OSCILLATOR ("CLOCK") (I)

RED SYMBOLS REFER TO LOCATIONS ON BLOCK DIAGRAM FOLD-OUT PAGE 56

The clock or master oscillator (1) is a stable, variable-frequency waveform generator, WHOSE FREQUENCY MAY BE CONTROLED BY AN EXTERNAL D.C. VOLTAGE (2)

There are two signal outputs of the clock or master oscillater. One is a square wave (3), the other, a sine wave. (4) The outputs are at the exact same frequency.

The function of the clock is to furnish the "driving-signals" to the device. It is also a means by which the inner workings of the device are "time-synchronised."

We refer to the output of the clock as "high frequency," (3) (4) because we count down (by means of a counter (III) to be described later) to the "frame frequency," thus establishing a frame rate. Frame rate is the rate at which we draw one complete figure or picture on the display scope.

Because the counter performs a fixed-ratio-countdown, the low frequency is always a lower multiple of the high frequency. Thus, by varying the high frequency, we automatically vary the low frequency or frame rate.

During this developmental period, we have been operating at frame rates between 24 and 30 cycles per second (CPS). 30 cps is desirable at this time because

a) The lighting in our workshop is such that at a lower frame rate, we see a bothersome flicker, and

b) It is very easy to synchronize the frequencies to the 60-cycle line (5) frequencys (just twice the frame rate) with a hand adjustment and thereby eliminate what is known as "hum" or line noise, which if not synchronized causes a slow wobble of the picture.

In the future, we will install a feedback timing control (11) in the counter circuit which will automatically synchronize all frequencies to the line (5) (60 CPS) and thus eliminate the necessity of hand adjustments and also assure an exact 24 CPS frame rate.

The square wave output (3) is fed directly into the counter. (11)
It is also fed into and is the driving signal for the horizontal deflection generator (101) of the skin scanner (93) (to be described later).

The sine wave output (4) is fed into two of the samplers (59) (126) (sampler gates to be described later), also into a 90 degree phase shifter (6) whose output now becomes a cosine wave (7) (in relation to the original sine wave) which is subsequently fed into the other set of samplers. Also both sine and cosine waves are fed into MULTIPLIERS ~~modulators~~ (to be described later).

The function of the clock may be taken over by the tape recorder, where the clock signals are recorded on one of the channels, and used as driving signals of the device, thus synchronizing all recorded signals with the "tape clock."

COUNTER TIMING CONTROL

The counter is a chain of bistable multivabrators. The input to the first BSMV in the chain is the high frequency square wave from the clock. The output of the first BSMV is a square wave which is exactly ½ the frequency of the input. Thus each BSMV in the chain halves its input frequency.

At the present time we have 9 BSMV's in the counter chain. This gives a countdown ratio of 512:1. Thus for a frame rate of 24 frames/sec., the high frequency must be 12,288 CPS.

There is nothing magic about this selected ratio of 512 to 1. The choice of it at this time was governed by the ease with which we are able to use the high frequency in the function (sine-cosine) generator network. If the frequencies used in that network get too high, the generator does not perform as well as we'd like it to. We have not had time to redesign the network. However, it works well up to 16 or 17 KC, easily allowing a 30 FPS frame rate.

Of course, the higher the frequency we use, the greater "bone skin" resolution we may have. (This will be explained later.)

The output of the first BSMV, besides being fed into the 2nd BSMV, is also fed into the delay multivibrators in the aforementioned sine-cosine function generator network, and acts as a driving signal for those delay MV's. In other words, it causes the delay MV's to allow a sampling of the sine-and cosine waves in the samplers at ½ the frequency of the sine- cosine waves in the samplers; i.e., there are 2 cycles to sample from. The significance of this is that we can get more than a 360° rotation of a bone. (To be described more fully.)

The timing control is a feedback network which automatically synchronizes all of the driving frequencies (i.e. High and Low) to the 60 CPS line-frequency, thus assuring an exact 24 FPS frame rate.

There are 2 inputs to the timing control: one is the 24 CPS from the counter, the other is 60 CPS from the power line. The 24 CPS frame rate is fed into a BSMV whose output is therefore 12 CPS. The line frequency (60 CPS) is fed into a 5:1 counter (binary feedback type) and its output is 12 CPS. These 2 frequencies are then fed into a phase-comparator. The output of the phase comparitor (a D.C. voltage) is fed into a D.C.-controlled oscillator (CLOCK) (1) whose mean output frequency will be the desired high frequency (3) which when fed into the front end of the counter (11), will produce 24 CPS (13) (as accurately as the line frequency is 60 CPS) at the back end of the counter. For use with a tape recorder, (8) the oscillator would be replaced by a motor speed governor (20), which would accurately regulate the tape speed (125), and thus the frequencies coming off the tape. (9) (10)

THE HIGH FREQUENCY SINE WAVE (8) RECORDED ON THE CLOCK-CHANNEL OF THE TAPE RECORDER IS OF CONSTANT AMPLITUDE EXCEPT FOR THE FRAME FREQUENCY (10), WHICH IS OF GREATER AMPLITUDE. THIS FRAME "MARKER" IS CLIPPED OFF AND SEPARATED (21) FROM THE REST OF THE SIGNAL. BOTH SIGNALS ARE "SQUARED-UP" (21) (22) BEFORE BEING USED AS DRIVING SIGNALS (23) (24) FOR THE DEVICE.

BONE GENERATOR (INCLUDES IV, V, VI + VII)

ELECTRONIC GATE-COMMUTATOR OR MONOSTABLE MULTIVIBRATOR CHAIN IV

The chain of monostable multivibrators IV (MSMV) is used as an electronic commutator which opens and closes a series of "bone" gates V in a sequential manner. In other words, the MSMV's furnish the driving (opening closing) signals (25) to the gates.

The input to the first MSMV in the chain is a frame-rate frequency pulse (13) (say 24 CPS) which comes from the counter. III When the pulse arrives, it causes the MSMV (26) to flip into its other (unstable) state, for a length of time as determined by its integral RC network. (27) By varying R, (27) the length of time during which the MSMV is in its unstable state may be varied. During this "open" time, a change in voltage occurs on one of its outputs. (25) This voltage is used to open a number of gates V connected to it. When the "open" time has lapsed, the MSMV automatically flips back into its original state (stable) and changes back the output (25) voltage driving the gates, thus closing them. During the flip-back, a ~~pulse~~ change in voltage similar to the one that caused the original flip is (13) generated at another output point, (28) and thence is sent to the next MSMV (29) in the chain where a similar operation occurs, thus opening the next group of associated gates for a time described by the R (30) associated with that 2nd MSMV. This commutating action continues until all the MSMV's in the chain IV have gone thru their individual cycles.

The "driving output" (25) of the MSMV's IV (shown in BLOCK DIAGRAM) is used to perform a number of tasks. For example, this output may be used to close the electronic switches across the integrating capacitors, (63) thus causing the display beam to "fly back" to its starting point. These signals are used therefore as inputs to the flyback circuit, VIII and this action will be described later in more detail. Another use of the MSMV output is to dim or blank-out the display beam. By applying the MSMV output to the grid of the display CRT, the beam is "turned-off" during the "open" time of the MSMV so engaged. In this manner, flyback retraces, and certain bone-placing retraces, may be blanked out as desired. (as in the arms, WHEN DRAWING A HUMAN FIGURE where the beam must move from the starting point, up to the shoulder and thence proceed to draw the arm, and during that "placement" bone drawing, the beam is blanked out)

As mentioned before, the length of time that an MSMV remains in its open position is determined by R of the integral RC network. Thus by varying each of the resistances associated with each MSMV-RC-network, an operator is able to "set-up" a figure or character to have the desired "bone" lengths, and overall structure. He also, in this setup procedure, determines the sequence in which the particular bones will be drawn. In determining this sequence he makes the necessary connections between the MSMV's and the flyback and blanking circuits, in addition to determining and "setting-up" the desired bone lengths.

The MSMV chain is a switching, commutating network which regulates the opening and closing of the "bone" gates. The various tasks which it performs could be done in other ways, such as (a) mechanical systems (b) binary counter systems with diode networks c.) other electronic arrangements d.) electro mechanical systems. FOR GREATER STABILITY WE MAY EVENTUALLY USE THIS SYSTEM.

BONE GATES V

Associated with each bone, and being driven by a MSMV of the IV MSMV chain, are a number of electronic gates (31) (32) etc. The gates are normally closed, but are opened by the rectangular wave form (25) received from their driving multivibrator. There is an output (33) from the gate only during the "open" period, and the nature or character of this output is governed by the input signal (34). If the input (34) is a D.C. signal, then the output (33) will be a corresponding D.C. signal (similarly if the input is a sine-wave or other shaped signal, the output will look like the input). In other words, the gate (31) passes or allows to pass thru it any signal that is present at its input (34) during the "open-period" of the gate.

The control voltages of the gates for each bone are in parallel, and operate the gates (31) (33) (36) (37) simultaneously, and send signals to different parts of the device in order to ~~"make"~~ generate bones and control their vectorial positions in space. A gated D.C. waveform (as will be shown later) makes a straight bone. A gated "shaped" wave form will make a bone whose axis is not straight, but has the integrated, vectorial direction (or shape) prescribed by the shaped input (34).

By varying the D.C. voltage applied to the first gate, (31)(32)(38)(39) the angle (θ) that the bone makes with the X-axis of the display is varied. A variable potentiometer may be used to vary this input voltage (other means may be used, of course). The second (35)(40)(41)(42) gate is used to control the angle that the bone makes with the X-Y plane (ϕ), in similar fashion by varying that D.C. input. The third (36)(43)(44)(45) gate is used to control the angular position (or may be called "rotational position") of the skin on the bone.

Additional gates may be used in similar fashion to control other parameters of the bone - such as intensity, (37) etc. texture, etc.

The first two gates called "θ" and "ϕ" send their output signals (33)(46) to similar, angle-producing (61)(128) VI VII networks. These and other gate signals may also be sent to corresponding channels of the XIII tape recorder, (117)(118) so that during playback these multiplexed signals will drive the bone and skin producing mechanisms of the device, thus automatically producing the previously recorded movements of the bones and associated parts.

The outputs of consecutive Θ gates are all fed into

(A7) VI

the "Θ" - sine-cosine function-generator and similarly the

(A8) VI

outputs of Φ gates into ~~the~~ ϕ sine-cosine function gen.

SINE - COSINE FUNCTION GENERATOR VI

There are two sine-cosine function generators. One receives its input from the θ gates, the other from the ϕ gates. Each generator has two outputs for each input. The range of voltages at the input represent any desired angular position of the bone, and the two voltage outputs have the relation of the sine and cosine respectively. (See General Theory)

In order to produce the relative values of the sine and cosine, samples of sine and cosine waves are taken simultaneously at regular intervals, and these samples are fed into capacitors which hold the sampled voltages to produce D.C. voltages across the capacitors which are at the levels being sampled.

A sine-cosine function generator has in its network a delay multivibrator, a narrow-output monostable multivibrator, 2 wave-sampling gates and a holding capacitor on the output of each sampling gate. The delay multivibrator has two inputs. One input comes from the 2nd stage of the counter, at ½ the high frequency and is of the square wave type. This input causes the delay multivibrator to change states (to flip). It will remain in this state until it flips back automatically into its original state. The length of time that it remains in the unstable state is determined by the 2nd input. This 2nd input (which comes from the gates) is a D.C. voltage whose value determines the length of time the delay M.V. will "delay". The "driving" input from the counter, as stated before, is at ½ the high frequency. This means that the delay M.V. performs its function once for every 2 cycles of the high frequency. This allows a sampling of the sine and cosine waves to be taken over 2 cycles of the waves, which allows for a bone-angle swing of more than 360° continuous.

The output of the delay M.V. is differentiated and clipped, so that only a narrow pulse representing the trailing edge of the change-of-states is sent on to the narrow-pulse MSMV.

The input to the narrow pulse MSMV is a narrow, trigger pulse coming from the delay MV. The output of the MSMV is a very narrow, straight sided pulse which is used to drive (or open) 2 sampling gates. The gates are very fast acting. Another input to the gates is a sine wave (to one) and a cosine wave (to the other) coming from the sinewave generator (clock) and from the phase-shifter respectively. Thus the output of the gates is a very narrow pulse whose height (or value of voltage) is determined by the time at which the sine and cosine waves were sampled, which time was determined by the trailing edge of the delay M.V., which time was determined by the D.C. voltage impressed upon it, this voltage having been determined by the output of the bone gates. The number of such pulses for any given D.C. value impressed upon the delay M.V. is determined by the length of any given bone, AND THE OPERATING FREQUE OF THE DELAY MV, WHICH IS ½ THE HIGH FREQ. THUS, BONE-LENGTH RESOLUTION IS HIGHER OR "FINER" WITH HIGHER DRIVING FREQUENCIES.

Because of the holding capacitor associated with the output of each sampling gate, there appears across each capacitor a D.C. voltage representing a particular value of sine or cosine. For a normal-length bone, the holding capacitor may receive 15 or 20 sampling pulses during the time the bone is being generated.

There are other ways of generating this sine-cosine function. One simple way would be to let the output of the bone gates supply voltage to associated sine-cosine potentiometers, but these pots are expensive and it would be required that there be one for each gate and controling inputs would have to be exclusively mechanical.

BONE INTEGRATORS VII

The integrator is a high gain amplifier which has a feedback capacitor to its input. Its function is to perform continuous mathematical integration of the signals presented to its input. There are three integrators in the bone generator, one for each geometric coordinate (ie, x, y, z) of three dimensional space.

If the input to an integrator is a D.C. voltage, the output is a ramp function. The initial conditions (starting voltages on the output which determine the starting point of each bone on the display) are determined by the voltage across the feedback capacitor. If there is no discharge of that capacitor between succussive integrations, then the bones generated by the integration of a sequence of D.C. voltages will be "joined together". Whenever the capacitor is discharged or "shorted out", the initial condition voltages are made zero, and the display beam returns to a "zero" or "starting" position. (The flyback circuit to be described performs the function of shorting out and discharging the capacitor as desired or required to draw a figure or image.)

The value of voltage presented to the input of an integrator determines the rate of change of voltage at the output (slope). If the input D.C. voltages to the x and y integrators represent the cos θ and sin θ respectively, then the output of the integrators when fed into the horizontal and vertical amplifiers on a display scope will cause the beam to draw a line on the scope whose angle to the horizontal is θ. SIMILARLY, ϕ MODULATES THE PROJECTED LENGTH OF THE BONE, THUS THE MULTIPLIERS COMBINE THESE FUNCTIONS. (ϕ θ)

The outputs of the combination of any two of the x, y, z, integrators when presented one to each of the verticle and horizontal deflection channels of the display CRT will give the projection of the figure (or image to be drawn) on the plane determined by the combination. For example, if the x and y integrator outputs are used, then the display will be a view which is the projection of the figure of the x, y plane. Similarly, if the y and z outputs are used, the view will be a projection of the figure on the y, z plane. Intermediate views may be obtained by combining all three integrator outputs in proper amounts; thus allowing an operator of the device to view the object or figure from any position. The function of combining these integrator outputs in a proper fashion is carried out by the "camera angle network" to be discussed later.

FLYBACK NETWORK VIII

The function of the flyback network is to short-cut or discharge the capacitors (c) associated with the integrators at desired times during the sequence of bones and at the end of each cycle of bone generation. Discharging of the capacitors causes the beam of the display CRT to fly back to the starting position.

An electronic switch discharges the capacitor. Pulses which close the switch come from an amplifier which is in turn fed by pulses (which are selected as desired) coming from selected multivibrators of the MSMV chain. Also, a pulse whose duration is determined by the time of the closing of the last MSMV to the beginning of a new cycle of the first MSMV is generated by a bistable multivibrator. This flyback bistable MV receives a pulse from the last MSMV as it closes. This pulse flips the BSMV and its output causes the switches to close. This BSMV stays in the "closed" state until it receives another input pulse which this time comes from the counter, the same pulse which starts the chain of MSMV's.

(91) Diodes connect all of the pulse imputs to the amplifier (86) which activatess the switched (84)(85)(86) so as to prevent pulses from feeding back into the gates (55) and thus causing them to operate out of sequence.

The electronic switches (84)(85)(86) remain closed during the duration of a pulse, be it long or short.

THERE IS A COLUMN OF GATES V (n+1) WHICH ARE ACTIVATED BY THE BSMV (59) OUTPUT. THESE ARE NOT USED AS REGULAR CONTROLING GATES, BUT MERELY TO KEEP THE GATE-OUTPUT-SIGNALS (33)(49) ET FROM DRIFTING AROUND DURING THE TIME BETWEEN THE END OF ONE FRAME AND THE BEGINNING OF ANOTHER; THUS KEEPING THE FUNCTION GENERATOR VI FROM GETTING TOO FAR OUT OF THE REGION OF THE VOLTAGES (47)(48) NORMALLY PRESENTED TO IT. THESE GATES MAY BE USED AS CONTROL GATES TO THE SERVOS (112) DURING THE TIME BETWEEN FRAMES. THIS MEANS THAT THE SERVOS WOULD RECEIVE ONE CONTROL PULSE EVERY $\frac{1}{24}$ OF A SECOND.

SKIN GENERATOR IX

The Skin Generator IX is a high speed commutator which conveys in proper sequence and synchronization the thickness information which is retained in a convienient form of information storage device of medium.

The function of the skin generator is to generate a video signal, the magnitude of which represents the orthogonal distance (or thickness) between the bone vector and the surface (of the skin) of the object or figure being drawn.

The Skin Generator is a flying spot scanner which scans a specially prepared photograph, the density of which contains the desired thickness information.

The flying spot scanner is a special (short persistance phosphor) cathode ray tube (CRT) in which the beam is caused to sweep out a perscribed raster (patern of lines). The beam produces a short-persistant spot of light on the face of the tube. This spot of light is optically conducted and focused on the photographic transparency which transmits varying amounts of light according to the film density. Thus the photographic transparency modulates the intensity of the light as the spot sweeps or scans across it. This modulated light is collected by a condensing lens and roughly focused on a photomultiplier tube which converts the modulated light into a voltage signal (video). (In general, this system acts as a high speed commutator, commutating many pieces of information in a desired stream or sequence. A TV camera is another example of a device which performs this continuous commutation).

The video signal is then added (vectorially speaking) to the bone signal, giving the positional information to the display beam which represents the thickness of the object or figure being drawn.

The movement of the flying spot is controled by deflection amplifiers in scanner. The controling deflection wave forms are generated in the horizontal and vertical deflection generators (saw tooth generators), which are synchronized and driven by an input from the clock.

The raster (pattern of movement of the spot) of the scanner is basically rectangular, with some localized modifications in the pattern for special, skin-distortion effects as in lip, eye, and other facial and plastic-type movements. (such as wrinkle effects which would be automatically developed as a function of associated bone angles).

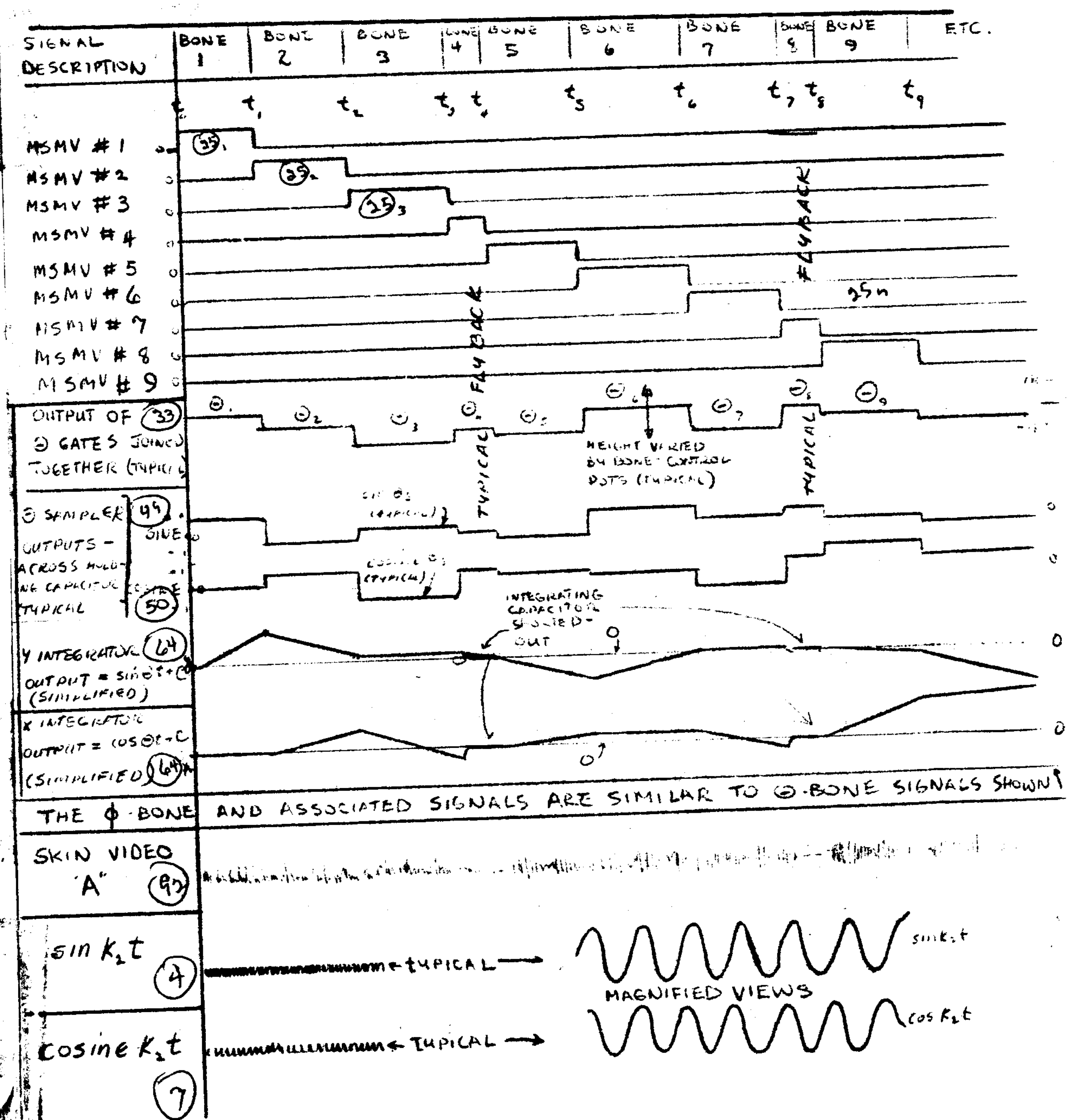
The skin generator may also be used to develope other skin information such as color, texture, and shading. (This will be discussed later.)

SKIN NETWORK X

The function of the skin network is to algebraically combine the various voltage representations of sin θ, cos θ, sin ϕ, cos ϕ, K_1t_x, K_1t_y, K_1t_z, sin K_2t, cos K_2t and the video signal "A", to give the proper formulamatic representations of the geometric projections of the figure or object being generated. For quick reference, a tabular explanation of these various signals is given below.

sin θ: cos θ :	D.C. values of voltage whose relationship is assthe sine and cosine of the angle θ
sin ϕ: cos ϕ:	D.C. values of voltage whose relationship is as the sine and cosine of the angle θ
K_1t_x K_1t_y K_1t_z	Ramp functions of voltage, the outputs of the integrators x, y and z respectively, where the constant K_1 is a scaling factor which is a device funtion; a lumped constant which takes into acopunt the gains of the horizontal and vertical amplifiess of the display, the gains of the integrating amplifiers, and the amplitude of the input sine and cosine high-frequency waves.
sin k_2t cos k_2t	Sine and cosine wave functions whose frequency (the high frequency) is determined by k_2, and whose amplitude is considered to be equal to one unit.(Normal mathematical representation would be: a sin k_2t, but for brevity we let $a = 1$ (unit) which may be about ten volts, peak to peak.(p-p).
A	Capital A is used to denote the video signal which comes from the skin-scanner. This is a typical wide band video signal whose upper frequencies are very high.

To show the inter-relationships of the various signals as a function of time, a signal plot is given below.



Two algebraic functions are performed by that portion of the device we call the skin network, namely multiplication and addition. Associated with each multiplier are input and output amplifiers, which are electronically necessary to allow an analogue multiplier to perform its tast of multiplication. Multipliers also require a "center-tap" input; thus there are three inputs to the multipliers. The important thing here is not how we perform the particular task, but that we do perform it. Adders are merely resistor netwoeks which add the various signals presented to it. If the signals are of opposite polarity the the adder actually performs a subtraction.

Algebraically speaking, the Skin Network takes the previously mentioned signals and combines them so that:

$$x = K_1 t_x \cos\theta \cos\phi + A \cos\theta \sin\phi \cos k_2 t - A \sin\theta \sin k_2 t$$

$$y = K_1 t_y \sin\theta \cos\phi + A \sin\theta \sin\phi \cos k_2 t + A \cos\theta \sin k_2 t$$

$$z = K_1 t_z \sin\phi + A \cos\phi \cos k_2 t$$

Here, x, y and z represent the x,y, and z vectorial components of the three dimensional figure. By presenting any two of these signals to the X and Y channels of a display CRT, the resulting drawing will be a projection of the three dimentional figure on the plane determined by the components selected.

By the geometric selection and combination of all three of these components, any view or projection of the three dimensional figure may be shown.

CAMERA-ANGLE NETWORK XI

VI

The function of the Camera-Angle Network is to algebraically combine (and thus geometrically and vectorially combine) the x, y and z components of the three-dimensional figure in such a manner as to allow for the selection and presentation of any 2-dimensional projection or view of the figure when the 2 outputs of this network are presented to the X and Y (horzontal and vertical) channels of a display CRT.

Two algebraic functions are performed. The first is multiplication by a constant, the second is addition.

Multiplication by a constant is, in effect, the " taking of the sine and cosine of the vector"x and is accomplished by a network of variable, sine-cosine potentiometers. Addition it performed by using a fixed-resistance network.

Angles Θ' (theta prime) and ϕ' (phi prime) represent the rotation of the xy plane about the x axis and xz plane about the z axis, respectively.

Two Sine-Cosine pots ganged together (ie; with wipers on a common shaft) is the mechanism for performing the properly-related multiplication by constants, ie; taking the sines and cosines in their proper relationship.

There are two such mechanisms. Rotation of the shaft of one controls the viewing angle Θ'. The other controls the viewing angle ϕ'. Amplifiers associated with the network of sine-cosine pots are an electronic necessity.

The two outputs (110) (111) of this network are fed into the X (104) and Y (105) channels of the display CRT, and represent the "beam-positional" information necessary to draw the figure. Controlling servo-motors (112) will be used to position the shafts of θ' and ϕ', so that the servo driving signals may be recorded on the control tape (magnetic) along with other control signals, thus recording the camera angles. In other words, by recording the servo input signals (112), the servos will automatically position the shafts (108) of the sine-cosine pots to give the desired viewing or camera angles on playback.

OVERLAP PREVENTION AND SCAN CONVERSION XII

Because the display beam is drawing a 2-dimensional projection of a 3-dimensional image in a continuous manner it is necessary to provide a means of preventing the beam from drawing over a portion of the image which has already been drawn. Thus a special device for "overlap prevention" (113) has the function of doing away with "ghost" image or overlap.

Overlap may be classified into two types. One type occurs when the "back part" or part of the image on the side away from the viewer is drawn. This overlap is prevented by turning off the intensity of the beam according to the vectorial position of the skin vector which is a function of 1) phase of the high frequency, (4) and 2) the camera angle XI (112) (which governs the position of the plane of projection).

The 2nd type of overlap occurs when one part of an object or figure overlaps another part, or where one figure is in front of another. By using a special display tube (113) which has in it, two or more electron guns, one of which is a "write" gun, another of which is an "erase" gun, (having selective erasure capability) and having the erase gun predede the write gun by employing a slight delay (114) in the "write" signals (both guns getting the same positional display signals, however) overlap may be prevented, as long as the object or part of the object which is to be displayed is drawn in sequence compatible with this method (namely, PARTS DRAWN last will show.)

A multi-gun scope thus employed will contain the image thus drawn for a length of time necessary for photographing or scan converting. A scan conversion tube may be used to tranform the drawn image into a scanning pattern which is compatible with television transmission or a close-line raster which would be compatible for the superposition of figures on a background.

At this point in the generation of animated pictures it is necessary to consider picture quality in terms of resolution. The problem of resolution becomes acute when high scanning speed necessitates high bandwidth requirements. Thus it is contemplated that the special picture techniques (superimposition-overlap prevention-scan conversion) will be carried on at a relatively slow rate - ie, not at the same apeed at which we animate. An operator may do his animation in real time (where the device puts the control signals into a 24/frame/sec format) but the eventual film-recording of the animated sequences will be at a slower rate, and of course all automatically controled by the pre-programmed animation.

With low, reproduction-scanning rates, high resolution cathode ray tube display, (compatible with 35mm film grain) may be attained.

RECORDING NETWORK XIII
(Tape Recorder)

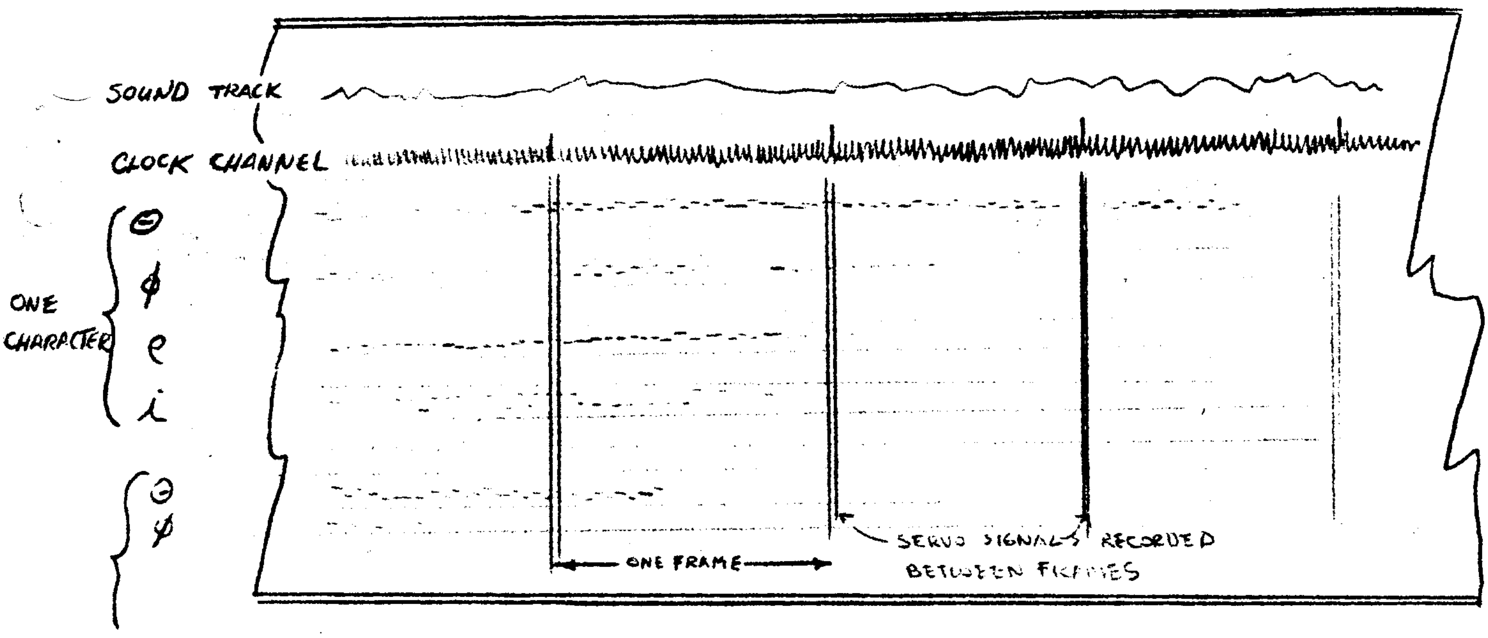
The function of the recording network is to record the joined-together gate-output signals (multiplexed angle-signals from the bone-gates) and allow for the play-back of these signals. The recorder is a multi-channeled recorder. On one channel is recorded the clock signals and frame-signals for synchronization. Sound is recorded on another.

Selective recording of individual gate-outputs or groups of gate-outputs is accomplished with recording gates which are activated (opened) by the M.S. multivibrators associated with the bone gates desired to be recorded. A switch may be employed to hold these recording gates opened if it is desired to record all of the bones. (as an operator may do at the beginning of an animation run.)

The "write" (record) heads are situated "upstream" from the "read" (playback) heads as far as tape motion is concerned. The signals which are passed by the recording gates are thence recorded on the tape by the "write" heads. The signals thus recorded are almost immediately read by the "read" heads from which the signals are amplified and sent into the bone generation network.

The tape format is shown below:

TYPICAL TAPE FORMAT



The clock channel has recorded on it the high frequency sine wave plus the intermittant frame pulse. These signals are electronically separated after reading, and the sine waves are sent to the bone generator and the frame pulses are sent to the counter chain.

After the θ and ϕ tape channels are filled with recorded signals, selective re-recording is accomplished by making connections between selected MSMV's and the ϕ recording gates so that these gates are opened only during the times of occurrence of the opening of the θ and ϕ gates associated with the selected MSMV's. (The initial recording switch is open~~ed naturally~~ AT THIS TIME.)

For example, suppose an operator wished to re-record the angular actions of the 4th and 5th bones. He'd connect the pulsed output of MSMV's #4 and #5 to the actuating input terminal of the <u>recording</u> gate. Thus the only time recording would take place would be at the exact spots on the tape that corresponded to the previously recorded actions of bones 4 and 5. The write head (123), in being activated at those times, would obliterate the previously recorded signals and leave the newly desired signals on the tape. The rest of the frame time the recording gates (119) (120) are closed. The read heads (124) pick up the old as well as the new signals and transmit (117) (118) them through the device (47) (48) ETC. to stimulate the desired action on the display.

Other tape channels are used in similar fashion to record and control other parameters of the bone. For example, the (rho) channel is used to control the rotational position (or twist) of the skin relative to the bone axis.

SHADING (AND COLOR) NETWORK (NOT SHOWN)

The electronic signals (110)(111) coming out of the camera angle network are beam-positioning signals; (just as fingers control the position of a pencil on paper). The function of the shading (and color) network is to govern the beam intensity as it draws the figure or object, ie. (high frequency) variations in intensity associated with skin shades and shadows, textures etc. which arise from the surface variations (94) in the skin. (Color variations in this sense are thought of in terms of a two or three-color (multi-color) process where, for example, the images of three display scopes (images identical on each) are optically superimposed, and each scope has a color filter on its face. By varying the intensities of the 3 beams, the optical image has full spectrum color capability. Thus this topic is called "shading (and) color network".)

The "skin" video signal (92) contains the information about the orthogonal distance between bone and skin (thickness). In the Full Basic Format, the rate-of-change of the video signal is used to control the brightness (shading) of high-frequency skin variations to accentuate skin features which occur between the edges of the object being drawn in this format by differentiating the skin video a rate-of-change signal is obtained. A threshold network (NOT SHOWN) detects all rates of change above a prescribed absolute value. The clipped output of the threshold network is amplified and scaled, thence used to modulate beam intensity.

Rounding, edge effects (edge shadows, etc.) are produced in accordance with the skin vector position which is a function of the phase of the high frequency (4) clock.

In addition, a high frequency wobble or a focus-flare may be employed to heavy-up or thicken the edges, this action also being synchronous with phase of the high frequency sine wave.(4)

Flat color effects, or grays, or textures which do not vary with bone position may be produced by gating-in these intensity-modulating signals using the bone gates (37)i desighed for that purpose, The input to the gates may be a high frequency of a certain pattern which when applied to modulate the beam intensity during the drawing of a particular bone will give a textured pattern. More specifically, video signals of prescribed desighs may be applied in this manner to give the desired exterior appearance of an object as a soap box or other consummer product, or a shirt pattern (on a human figure) or a fur pattern (on an animal character). (To generate this intensity video, another scanner technique where optical means (2-way mirrors) are used to have the skin-scanning raster of the flying spot focused on two (or more) films - where one film contains thickness information (94) and another contains surface color, pattern or texture information.

CONTROL OF MOTION AND OTHER PARAMETERS

By controling the voltage inputs (34) to the bone gates, (31)(32) ETC (35)(36) ETC the brightness positions, attitudes, plastic distortions (103) and other spacial parametors are controled. The function of the controls is to generate the desired signals for ######## the various motions, etc. In general the controlling signals are very low frequency and in some cases practically D.C. (The sampling rate for each bone signal to be multiplexed is 24 times per second. In one second, unless the action of a bone is very swift, the voltage variation from the beginning to the end of one drawing cycle (1/24 sec.) of one bone IS 1/30(1/24) or 1/720 sec.) WHICH ~~is~~ is very slight. That is to say, suppose the voltage varies .5 volts in one second due to the turning of a potentiometer in order to change the angle of the bone, then the variation from the beginning to the end of a bone is about 1/140 volts which is such a small change that the bone appears straight.)

Networks of variable resistors and very low-frequency generators may be used to generate ~~interrupted~~ INTERRELATED bone-group actions or motions. As the manipulation of the potentiometer inputs is simplified, it may be considered that the "controls" may become more and more computer-like, where many bone-motion functions are generated automatically.

Shaped waveforms in place of D.C. inputs into the bone gates (34) will give generate bones other that straight. For example, a saw-tooth control input will make a wiggly bone; A sinosoidal input (if at the proper phase and frequency) will make a circular bone ie. a circle; a square (type) wave input will make a zig zag or saw-tooth thpe bone; a ramp input to the bone gates will make a curved or arched bone.

Special controlling waveforms may also be inserted either before or after the integrator, (63) (64) without passing through the bone-gating V and sampling networks VI in order to produce desired mutations on the bones. (Techniques such as these have been discussed on many occasions and will be executed when time allows.)

Joy-sticks and finger controls have been designed for easy, mechanical manipulation of the controls and may be the subjects of later patents. Special controlling inputs (103) for facial expressions may be tranduced from actual facial and lip motions using a network of strain gages.

OVERALL OPERATION

As is contemplated at this time, operation of the device will be in accordance with the various modes described here.

Mode I: Character Information Input

Specially prepared photographic transparencies (94) containing information necessary for character and backgroung generation are put into the device. Corresponding bone lengths are set, either by hand manipulation of "length pots" (27) or by the insertion of a prepared "resistor card" (not shown). Bone sequence is "programmed" (including flybacks) by making the desired interconnections of the MSMV (25)↔(88) chain.

Mode II: Set Up

The primary set-up-control potentiometers (34) (ONE FOR EACH GATE) are manipulated to put the character or characters in a desired, neutral position. The primary recording gate switch (122) is closed and the recorder is activated to record a length of time corresponding to the scene-length (which is governed by the pre-recorded sound track). The tape is then returned to its starting position. (This may be called "the initial tape pass".)

Mode III: Animation

With the initial recording gate (122) open, but with the desired bones in the record mode (121) (ie. (125)n with MSMV hook-up to recording gate) animation is effected by manipulation (either electronic, electro mechanically, or hand mechanically) of the bone gate inputs of the bones being animated. (This may be called "animation pass".) Subsequent animation passes are made until the desired sequence of action is obtained. (Skin may or may not be in place at this times)

Mode IV: Full Animation Check

In this mode, the device is run at a slower speed to allow the complete fabrication of the scene, including skin drawing, shading, background superposition, etc., so as to allow inspection of the completed scene.

Mode V: Photographic Recording

The device is run at the slower, photographic-recording speed while the individual frames of film are exposed to the sequence of pictures generated automatically by the device, having previously been programmed in Mode ~~II~~ III.

GENERAL THEORY OF BONE GENERATION

A display scope or standard, electrostatically-deflected cathode ray tube acts as a vector-component-adder if the proper time-variant signals are presented to the x and y plates. Fig I shows a vector of length L which makes an angle Θ with the X axis.

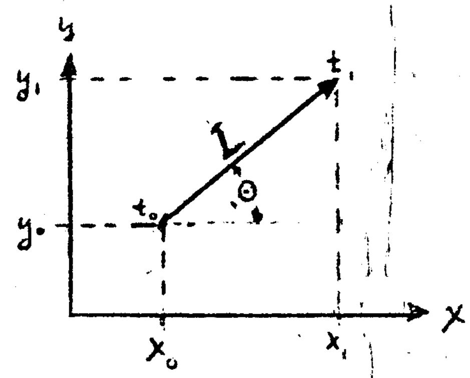


FIG. 1

One representation of this function in the x, y coordinate system is

$$y = f(t) \qquad \text{(function of time)}$$
$$x = f(t)$$

Which is a parametric repr§sentation of that line which starts at t_0 and goes to t_1. The functions of time f(t) are ramp functions and may be plotted as shown in fig 2.

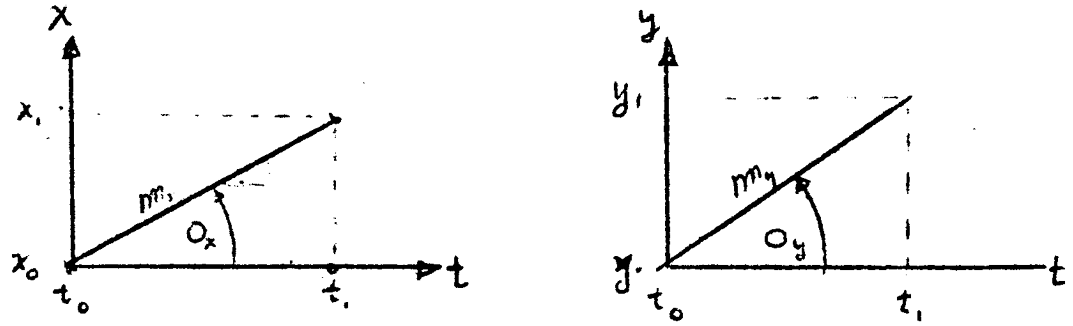


FIG. 2

Fig 2 shows that in the time t_0 to t_1, x and y increase from x_0 to x_1, and y_0 to

y_1 respectively. m_x and m_y represent the slopes of the x and y functions. An algebraic representation of these ramp functions are:

$$x = m_x t \qquad \text{and} \qquad y = m_y t$$

where m_x and m_y are constants which represent the slopes of the lines in fig. 2, and t is the time variable.

These slopes are the same as the tangents of the angles 0_x and 0_y and

$$\tan 0_x = m_x = \frac{x_1 - x_0}{t_1 - t_0} ; \qquad \tan 0_y = m_y = \frac{y_1 - y_0}{t_1 - t_0}$$

Figure 1 shows that

$$t_1 - t_0 = L \qquad (L = \text{length of vector from } t_0 \text{ to } t_1)$$

Figure 1 also shows that

$$\sin \theta = \frac{y_1 - y_0}{L} \qquad \text{and} \qquad \cos \theta = \frac{x_1 - x_0}{L}$$

Then by substituting equals we see that

$$\sin \theta = \frac{y_1 - y_0}{L} = \frac{y_1 - y_0}{t_1 - t_0} = m_y = \tan 0_y ; \qquad \text{and}$$

$$\cos \theta = \frac{x_1 - x_0}{L} = \frac{x_1 - x_0}{t_1 - t_0} = m_x = \tan 0_x .$$

Therefore the algebraic representations of the functions in figure 2 are::

$$x = \cos \theta \, t \qquad \text{and} \qquad y = \sin \theta \, t$$

t = t₁

where cos θ and sin θ are constants which represent the slopes of the ramp functions of figure 2, which are also the time-variant, parametric representations (simultaneous equations) of the vector components of figure 1.

We know that the indefinite integral of a constant (K) in the time domain is given by

$$x = \left[f(t)\right] = \int K\,dt = Kt + C$$

where C represents the initial condition criteria.

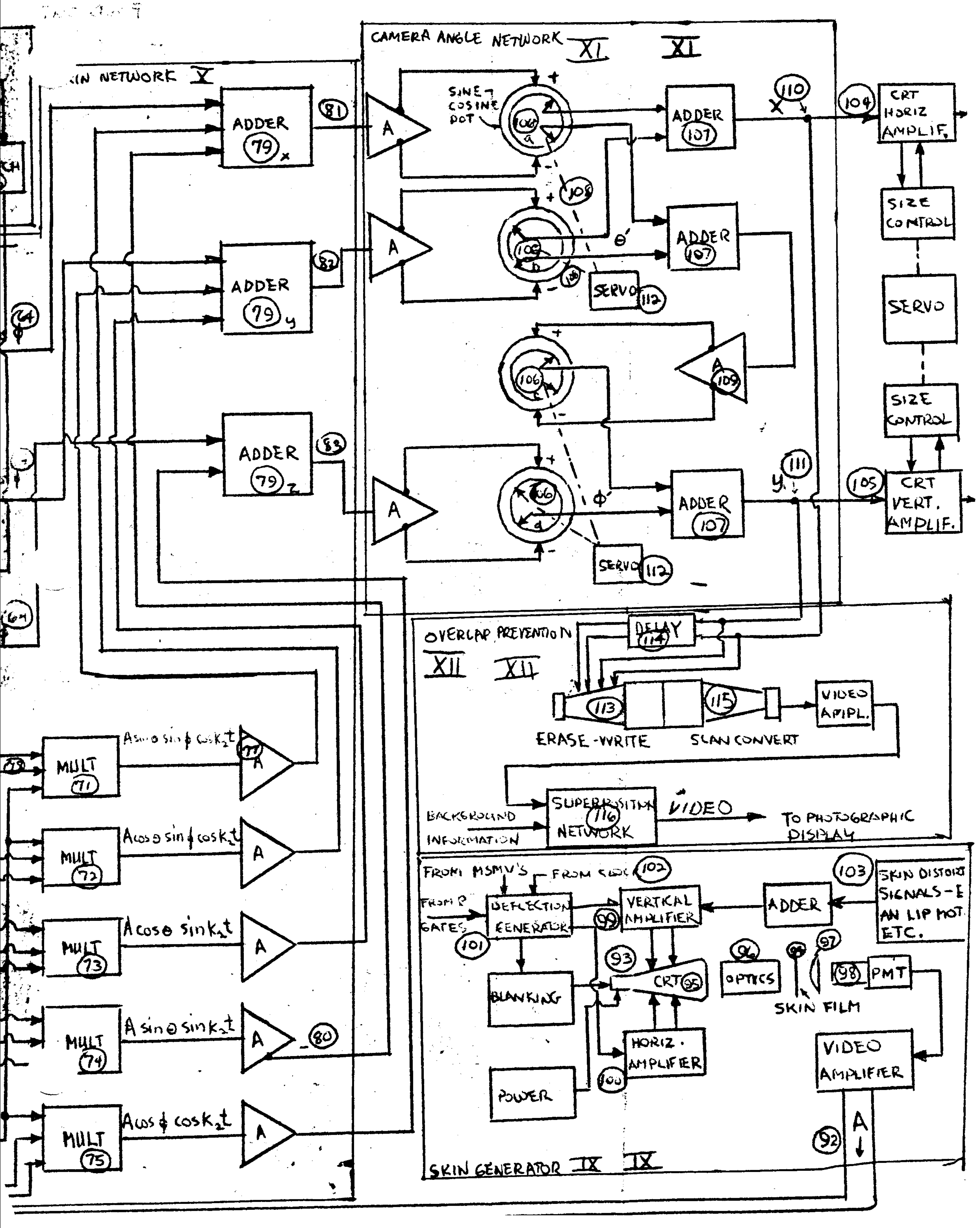
If for K we substitute sin θ, cos θ, we get

$$x = \left[f(t)\right] = \int \cos\theta\,dt = \cos\theta\;t + C_x$$

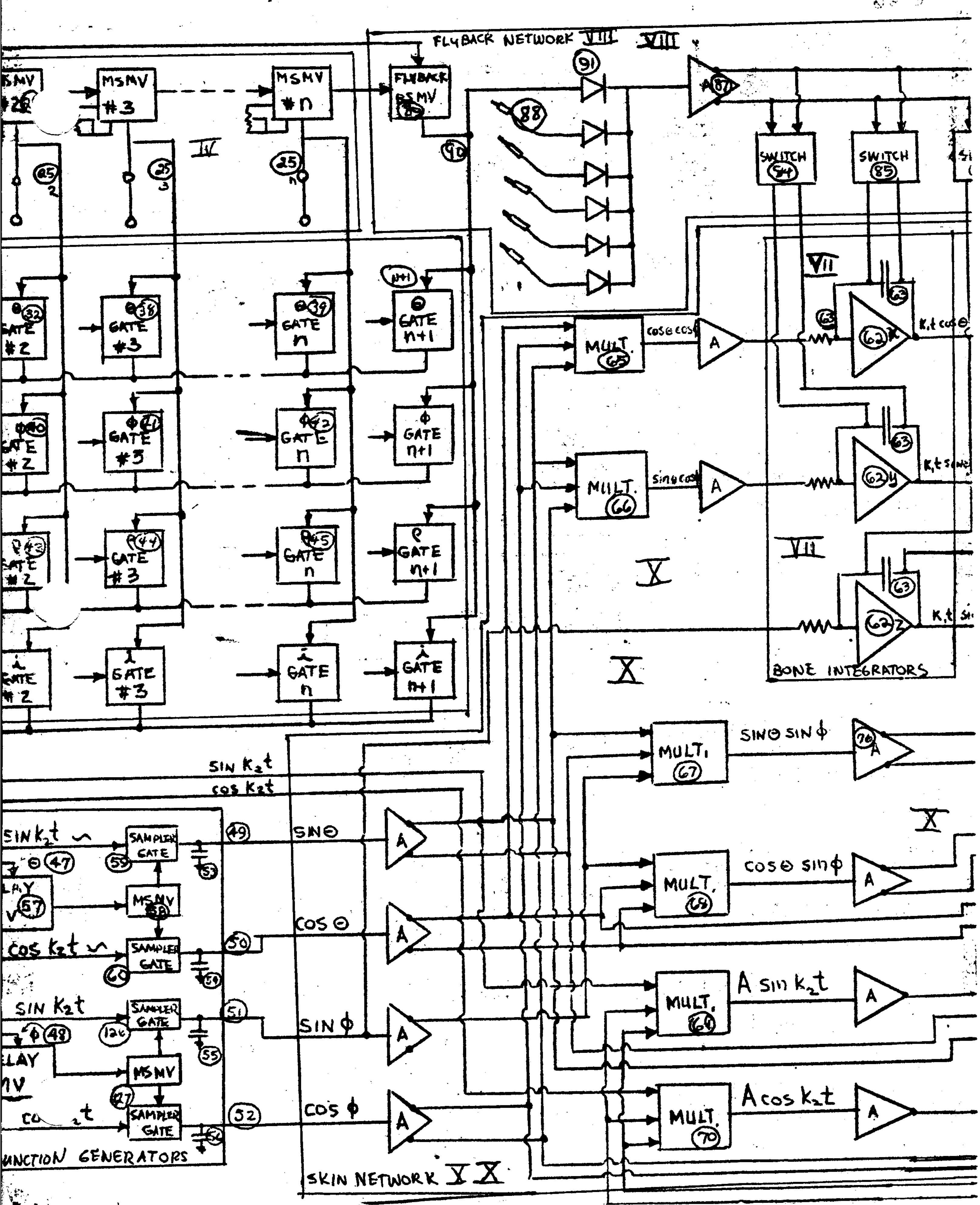
and

$$y = \left[F(t)\right] = \int \mathrm{SIN}\,\theta\,dt = \sin\theta\;t + C_y$$

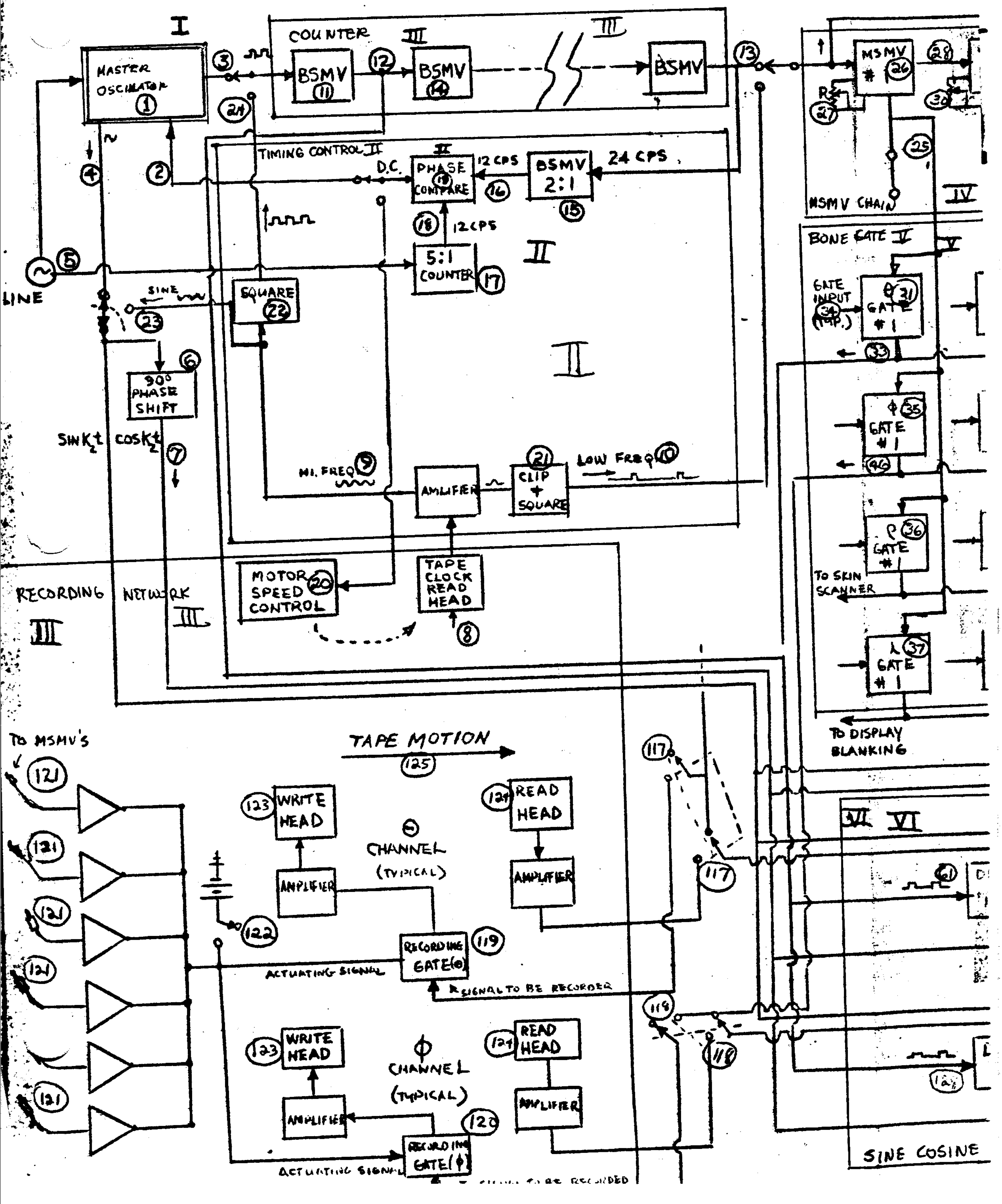
In order to produce the desired signals electronically which will give ramp functions which represent the vectorial components of figure 1, we must perform two simultaneous integrations of two constant (D.C.) signals whose relationship to one another is as the sine and cosine of the given angle.



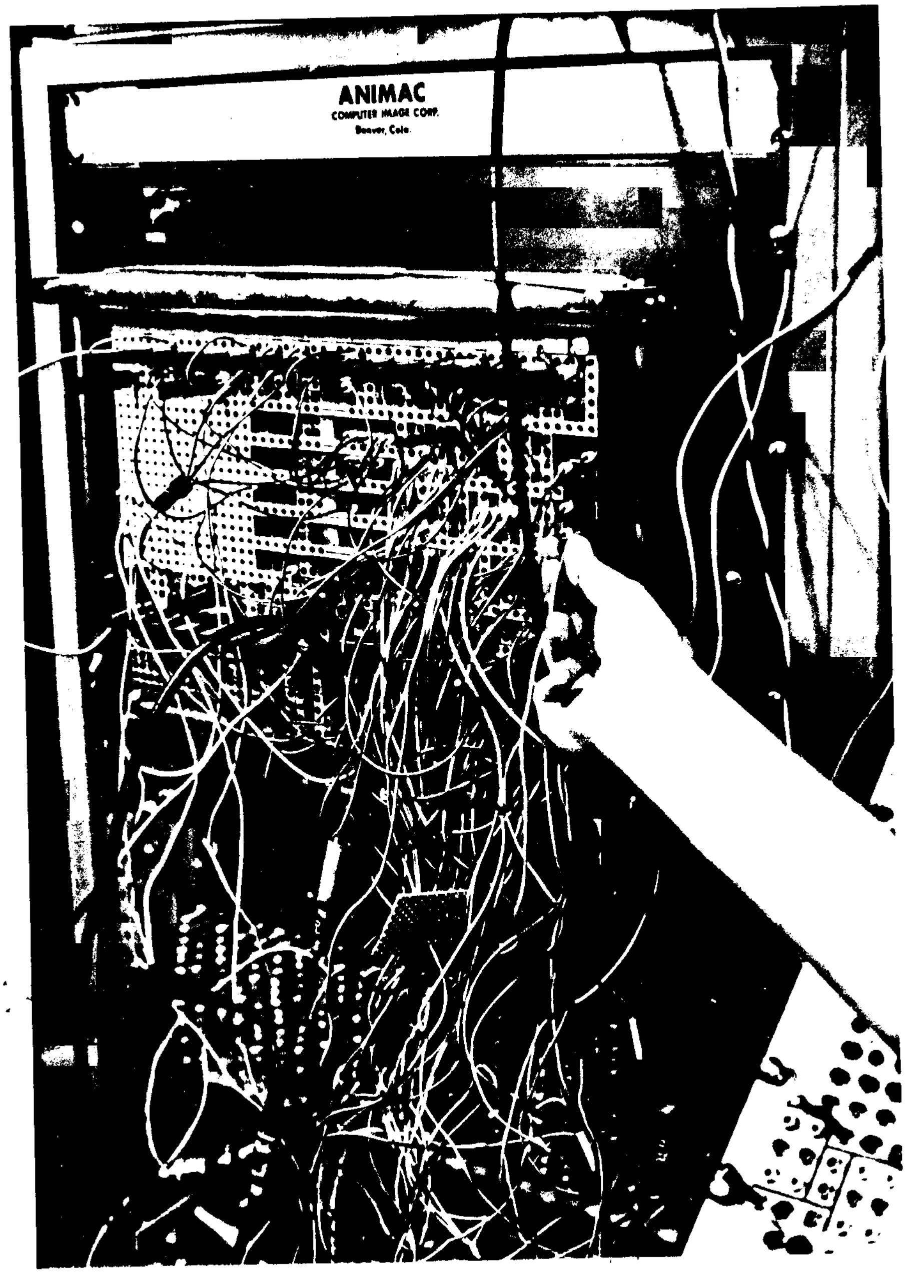
CAMERA ANGLE NETWORK XI XI
NETWORK X
ADDER 79 x
ADDER 79 y
ADDER 79 z
81
82
83
A
SINE-COSINE POT
106
108
ADDER 107
110
104
CRT HORIZ AMPLIF.
SIZE CONTROL
SERVO
SIZE CONTROL
CRT VERT. AMPLIF.
105
111
SERVO 112
109
θ'
φ'
OVERLAP PREVENTION
XII XII
DELAY 114
113
115
ERASE-WRITE
SCAN CONVERT
VIDEO AMPL.
SUPERPOSITION 116 NETWORK
VIDEO
TO PHOTOGRAPHIC DISPLAY
BACKGROUND INFORMATION
MULT 71
MULT 72
MULT 73
MULT 74
MULT 75
A sinθ sinφ cosk2t
A cosθ sinφ cosk2t
A cosθ sink2t
A sinθ sink2t
A cosφ cosk2t
77
80
64
FROM MSMV'S
FROM CLOCK
102
103
FROM P GATES
DEFLECTION GENERATOR
101
VERTICAL AMPLIFIER
99
ADDER
SKIN DISTORT SIGNALS - E AN LIP MOT. ETC.
93
CRT 95
OPTICS
96
97
98
PMT
BLANKING
SKIN FILM
HORIZ. AMPLIFIER
100
POWER
VIDEO AMPLIFIER
92
SKIN GENERATOR IX IX



FLYBACK NETWORK VIII
VIII
MSMV #2
MSMV #3
MSMV #n
FLYBACK MSMV
IV
VII
BONE INTEGRATORS
X
SIN K2t
COS K2t
SIN θ
COS θ
SIN φ
COS φ
SAMPLER GATE
MSMV
SIN θ SIN φ
COS θ SIN φ
A SIN K2t
A COS K2t
MULT.
SWITCH
GATE #2
GATE #3
GATE n
GATE n+1
FUNCTION GENERATORS
SKIN NETWORK XX



I
COUNTER III
MASTER OSCILLATOR 1
BSMV 11
BSMV 14
BSMV
III
MSMV # 26
TIMING CONTROL II
PHASE COMPARE
12 CPS
BSMV 2:1
24 CPS
D.C.
12 CPS
5:1 COUNTER 17
II
MSMV CHAIN
IV
BONE GATE V
GATE INPUT (TYP.)
GATE #1
LINE
SINE
SQUARE 22
II
90° PHASE SHIFT
SIN K/2 t
COS K/2 t
HI. FREQ
AMPLIFIER
CLIP + SQUARE
LOW FREQ
GATE #1
GATE #1
TO SKIN SCANNER
GATE #1
TO DISPLAY BLANKING
MOTOR SPEED CONTROL 20
TAPE CLOCK READ HEAD
RECORDING NETWORK III
TO MSMV'S
TAPE MOTION 125
WRITE HEAD
READ HEAD
CHANNEL (TYPICAL)
AMPLIFIER
AMPLIFIER
RECORDING GATE(θ)
ACTUATING SIGNAL
SIGNAL TO BE RECORDED
VI VI
WRITE HEAD
READ HEAD
φ CHANNEL (TYPICAL)
AMPLIFIER
AMPLIFIER
RECORDING GATE(φ)
ACTUATING SIGNAL
SIGNAL TO BE RECORDED
SINE COSINE


ANIMAC
COMPUTER IMAGE CORP.
Denver, Colo.