



This Circuit Generates a DC Voltage Proportional to Θ in response to input voltages proportional to $\sin(\omega t)\sin(\Theta)$ and $\sin(\omega t)\cos(\Theta)$ and an auxiliary input voltage proportional to $\sin(\omega t)$.

as inputs to block 5, which contains logic circuitry that determines the magnitude and trigonometric quadrant of the phase difference, and generates a logic-level pulse-width-modulated signal, $PWM(\Theta)$, in which the pulse width varies continuously with Θ . The quadrant-detection function eliminates the difficulty, encountered in prior analog arctangent circuits, caused by the discontinuity of the $\tan(\Theta)$ at $\Theta = \pm 90^\circ$.

$PWM(\Theta)$ is fed to block 6, which responds by generating a PWM waveform that switches between precise reference voltage levels of +10 and -10 V. This waveform is processed by a two-pole, low-pass filter (block 10), which filters out the carrier-frequency component. The output of block 10 is a DC potential, proportional to Θ , that ranges continuously from -10 V at $\Theta = -180^\circ$ to +10 V at $\Theta = +180^\circ$.

This work was done by Dean C. Alhorn, David E. Howard, and Dennis A. Smith of Marshall Space Flight Center.

This invention has been patented by NASA (U.S. Patent No. 6,138,131). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.a.nabors@nasa.gov. Refer to MFS-31219.

Advanced Three-Dimensional Display System

The display can be viewed from almost any direction, without special eyeglasses.

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A desktop-scale, computer-controlled display system, initially developed for NASA and now known as the VolumeViewer®, generates three-dimensional (3D) images of 3D objects in a display volume. This system differs fundamentally from stereoscopic and holographic display systems: The images generated by this system are truly 3D in that they can be viewed from almost any angle, without the aid of special eyeglasses. It is possible to walk around the system while gazing at its display volume to see a displayed object from a changing perspective, and multiple observers standing at different positions around the display can view the object simultaneously from their individual perspec-

tives, as though the displayed object were a real 3D object.

At the time of writing this article, only partial information on the design and principle of operation of the system was available. It is known that the system includes a high-speed, silicon-backplane, ferroelectric-liquid-crystal spatial light modulator (SLM), multiple high-power lasers for projecting images in multiple colors, a rotating helix that serves as a moving screen for displaying voxels [volume cells or volume elements, in analogy to pixels (picture cells or picture elements) in two-dimensional (2D) images], and a host computer. The rotating helix and its motor drive are the only moving parts. Under control by the host

computer, a stream of 2D image patterns is generated on the SLM and projected through optics onto the surface of the rotating helix.

The system utilizes a parallel pixel/voxel-addressing scheme: All the pixels of the 2D pattern on the SLM are addressed simultaneously by laser beams. This parallel addressing scheme overcomes the difficulty of achieving both high resolution and a high frame rate in a raster scanning or serial addressing scheme.

It has been reported that the structure of the system is simple and easy to build, that the optical design and alignment are not difficult, and that the system can be built by use of commercial off-the-shelf

products. A prototype of the system displays an image of 1,024 by 768 by 170 (=133,693,440) voxels. In future designs, the resolution could be increased. The maximum number of voxels that can be generated depends upon the spatial resolution of SLM and the speed of rotation of the helix. For example, one could use an available SLM that has 1,024 by 1,024 pixels. Incidentally, this SLM is capable

of operation at a switching speed of 300,000 frames per second.

Implementation of full-color displays in future versions of the system would be straightforward: One could use three SLMs for red, green, and blue, respectively, and the colors of the voxels could be automatically controlled. An optically simpler alternative would be to use a single red/green/ blue light projector and

synchronize the projection of each color with the generation of patterns for that color on a single SLM.

This work was done by Jason Geng of Genex Technologies, Inc., for Stennis Space Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center, (228) 688-1929. Refer to SSC-00205.