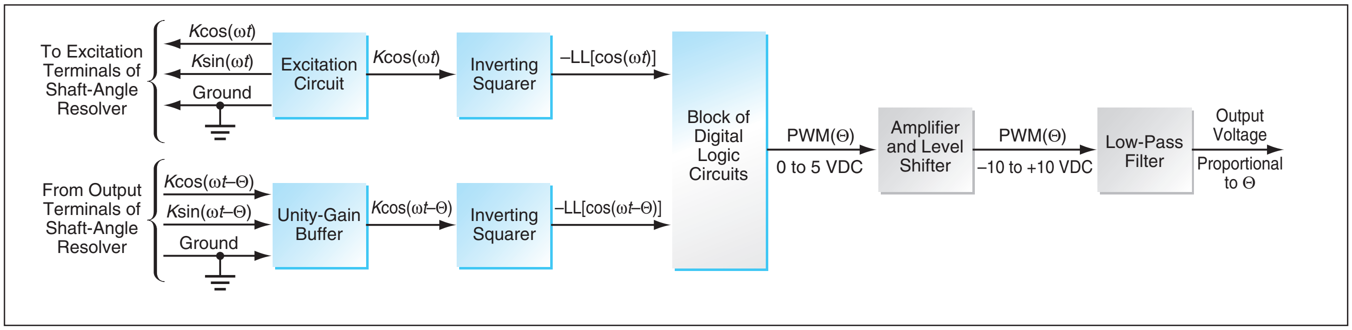


The **Resolver-to-Linear-Analog Converter** is depicted here in simplified form. This circuit provides excitation for a shaft-angle resolver and generates a DC output voltage proportional to the shaft angle, Θ.

gains and phases. These disadvantages are overcome by the design of the present circuit.

The present circuit (see figure) includes an excitation circuit, which generates signals $K\sin(\omega t)$ and $K\cos(\omega t)$ [where K is an amplitude, ω denotes $2\pi \times$ a carrier frequency (the design value of which is 10 kHz), and t denotes time]. These signals are applied to the excitation terminals of a shaft-angle resolver, causing the resolver to put out signals $C\sin(\omega t - \Theta)$ and $C\cos(\omega t - \Theta)$. The cosine excitation signal and the cosine resolver output signal are processed through inverting comparator circuits, which are configured to function as inverting squarers, to obtain logic-level or square-wave signals –LL[cos(ωt)] and –LL[cos(ωt – Θ)], respectively. These signals are fed as inputs to a block containing digital logic circuits that effectively measure the phase difference (which equals Θ between the two logic-level signals). The output of this block is a pulse-width-modulated signal, PWM(Θ), the time-averaged value of which ranges from 0 to 5 VDC as Θ ranges from –180 to +180°.

PWM(Θ) is fed to a block of amplifying and level-shifting circuitry, which converts the input PWM waveform to an output waveform that switches between precise reference voltage levels of +10 and –10 V. This waveform is processed by a two-pole, low-pass filter, which removes the carrier-frequency component. The final output signal is a DC potential, proportional to Θ that ranges continuously from –10 V at Θ = –180° to +10 V at Θ = +180°.

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

This invention has been patented by NASA (U.S. Patent No. 6,104,328). 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-31237.

Continuous, Full-Circle Arctangent Circuit

The discontinuity of the tangent function at 90° causes no trouble.

Marshall Space Flight Center, Alabama

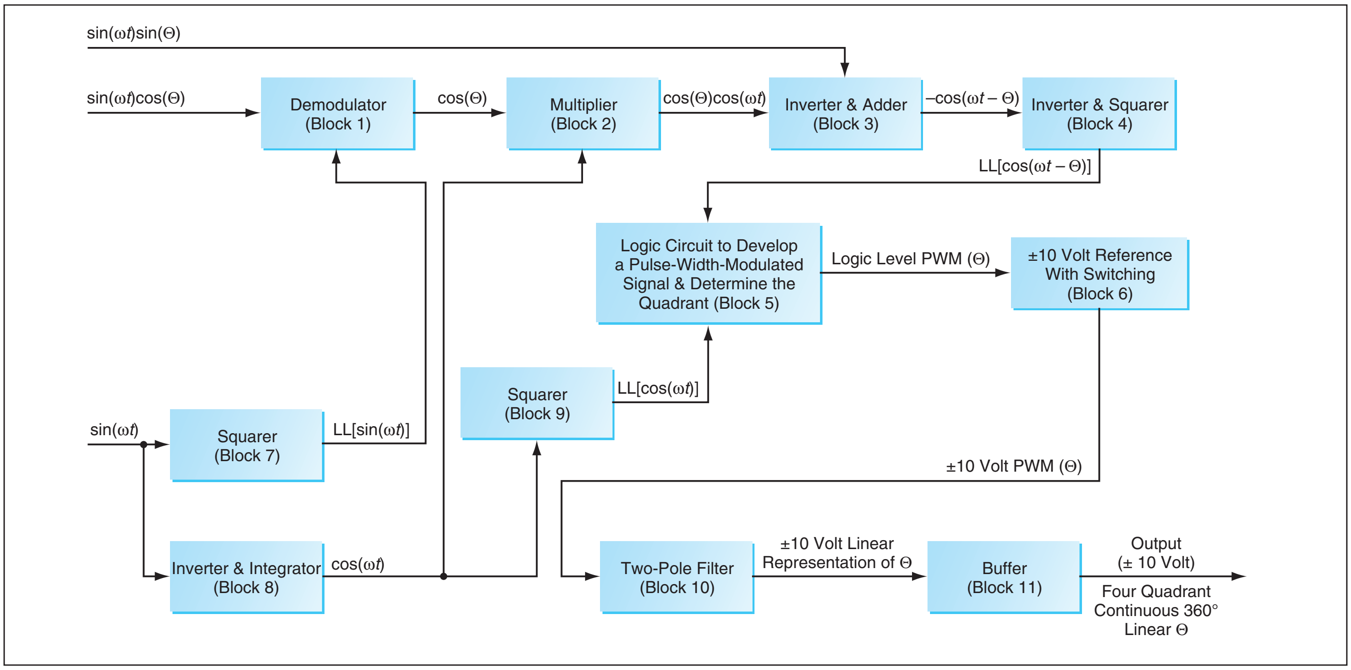
A circuit generates an analog voltage proportional to an angle, in response to two sinusoidal input voltages having magnitudes proportional to the sine and cosine of the angle, respectively. That is to say, given input voltages proportional to $\sin(\omega t)\sin(\Theta)$ and $\sin(\omega t)\cos(\Theta)$ [where Θ denotes the angle, ω denotes $2\pi \times$ a carrier frequency, and t denotes time], the circuit generates a steady voltage proportional to Θ. The output voltage varies continuously from its minimum to its maximum value as Θ varies from –180° to 180°. While the circuit could accept input modulated sine and cosine signals from any source, it must be noted that such signals are typical of the outputs of shaft-angle resolvers in electromagnetic actuators used to measure and control shaft angles for diverse purposes like aiming scientific instruments and adjusting valve openings.

In effect, the circuit is an analog computer that calculates the arctangent of the ratio between the sine and cosine signals. The full-circle angular range of this arctangent circuit stands in contrast to the range of prior analog arctangent circuits, which is from slightly greater than –90° to slightly less than +90°. Moreover, for applications in which continuous variation of output is preferred to discrete increments of output, this circuit offers a clear advantage over resolver-to-digital integrated circuits.

The figure depicts the main functional blocks of the arctangent circuit. In addition to the aforementioned input signals proportional to $\sin(\omega t)\sin(\Theta)$ and $\sin(\omega t)\cos(\Theta)$, the circuit receives the carrier signal proportional to $\sin(\omega t)$ as an auxiliary input. The carrier signal is fed to a squarer (block 7) to obtain an output square-wave or logic-level signal, LL[sin(ωt)]. The demodulator (block 1) uses LL[sin(ωt)] to demodulate input signal $\sin(\omega t)\cos(\Theta)$, generating an output proportional to $\cos(\Theta)$.

The carrier signal $\sin(\omega t)$ is also fed to an integrator and inverter (block 8) to obtain a signal proportional to $\cos(\omega t)$. The $\cos(\omega t)$ signal is fed to a squarer (block 9) to obtain a logic-level signal LL[cos(ωt)]. The $\cos(\Theta)$ and $\cos(\omega t)$ signals are fed to a multiplier (block 2) to obtain a signal proportional to $\cos(\Theta)\cos(\omega t)$. This signal and the input $\sin(\omega t)\sin(\Theta)$ signal are fed to an inverter and adder (block 3) to obtain a signal proportional to $-[\cos(\Theta)\cos(\omega t) + \sin(\Theta)\sin(\omega t)]$, which, by trigonometric identity, equals $-\cos(\omega t - \Theta)$. This signal is processed by an inverter and squarer (block 4) to obtain a logic-level signal LL[cos(ωt – Θ)].

The signal LL[cos(ωt)] from block 9 and the signal LL[cos(ωt – Θ)] from block 4 have the same frequency but differ in phase by Θ. These signals are fed



This Circuit Generates a DC Voltage Proportional to Θ in response to input voltages proportional to sin(ωt)sin(Θ) and sin(ωt)cos(Θ) and an auxiliary input voltage proportional to sin(ωt).

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(Θ), 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(Θ) at Θ = ±90°.

PWM(Θ) 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 Θ = –180° to +10 V at Θ = +180°.

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.

Stennis Space Center, Mississippi

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 perspectives, 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