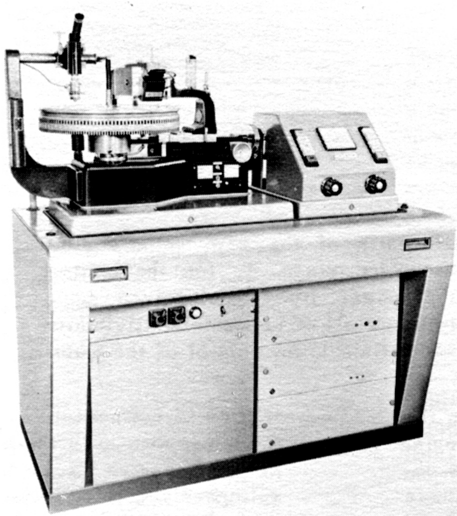

# DISK CUTTING MACHINE....... COMPUTER CONTROLLED

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**Following a brief historical introduction, this article delves into the precision which characterizes the present state of the art in disk recording technology, and from them deduces the performance criteria of a modern disk recording system. The most meaningful solution of these requirements is to be found in the use of semi-conductor technology; i.e., the replacement of all relays by electronically operating flip-flops. The control of the pitch drive motors is electronically solved. The transistor functions and circuits are described in detail.**

**History:**

More than a century has elapsed since the first preliminary efforts were made in the mechanical sound recording field. In the year 1859, an Englishman named L. Scott successfully recorded speech sounds via a membrane and needle on ...p black coated paper. Twenty years ...er, Edison invented the first actual recording process by substituting a tin cylinder for the lamp black paper, enabling the playback of the sound via needle and membrane. The phonograph record in its present form goes back to Emile Berliner (1887), who substituted the lateral cutting method used to this day, in place of Edison's vertical or "hill and dale" recording.

**State of the Art:**

In spite of the 87 year old tradition of of disk recording, there are still decisive improvements possible both with respect to technical matters, such as stereophony and tracing correction, and manufacturing. The following facts will serve to underline today's demand placed on disk recording precision. The excursion of a groove for a peak recording level at 1 kHz of 8 cm/sec. is ±15.9 micron (approx. ±0.7 mils). Disk reproduction of a signal of -60 dB is still audible. That means that the cutting stylus records an amplitude of ±0.0007 mils or 7 x 10 -7 inches. This excursion equals the wavelength of soft x-rays! The grooves on a disk have an average width of 2 mils and a spacing of .5 mils. The sum of these equals the thickness of a human hair. The pitch control, therefore, must be accurate to a fraction of a hair to prevent overcutting to the neighboring groove.

These two magnitudes are characteristic for the required precision in the industrial manufacture of phonograph records. The pitch control system for cutterheads must, therefore, be highly insensitive to disturbances of both an electrical and mechanical nature. The lead screw drive system must be continuously and reproducibly variable, and the amplifier system for the cutterhead must be devoid of any extraneous impulses.

**New Developments Using Solid State Technology:**

The new Disk Cutting Lathe, VMS-66, was developed in concert with the TELDEC Company and the Albrecht Company, both of Berlin. On the one hand it conforms to the most critical demands for precision; on the other, it is simple and automated. Since the cutting of acetate masters requires a large number of switching functions, and relay contacts are a constant source of electrical disturbance, the VMS-66 replaces all relays with silicon transistor flip-flops. The entirely altered operating principles of electronic switching also required a new control system offering greater flexibility and simplicity in operation. The high life-expectancy of the silicon transistors used can likewise be regarded as an important improvement.

The most cogent operation simplification is represented by the programmer plug with which the entire disk cutting system is converted from one type of disk to another in a matter of seconds. Every desired combination of rotational speed (16-2/3, 22-1/2, 33-1/3, 45 and 78 rpm)* with any diameter (7", 10" or 12") may be selected. The required 20 function conversions are all effected through each programmer plug, which contains a number of passive circuit elements: 4 switching modes, 7 level changes, 9 time delay adjustments.

**The Motor Control:**

This simplification was made possible in the main through the use of an electronic speed control of the pitch drive motor. The amplitude dependent pitch drive requires rpm change of 1:3 within 0.1 seconds. Since such acceleration can only be obtained from motors with a minimal rotor mass, the VMS-66 is pitch driven, using Ferraris motors. Taking into consideration turntable speeds between 16-2/3 and 78 and the amplitude dependent pitch control, the motors must be capable of a control range of 1:22. The Ferraris principle is actually unsuited to such a range if a usable amount of power is to result, and it was only the advent of completely electronic control which made gear switching between turntable speeds unnecessary. Figure 1 shows the function block schematic of the new motor control with its operational elements. A power line

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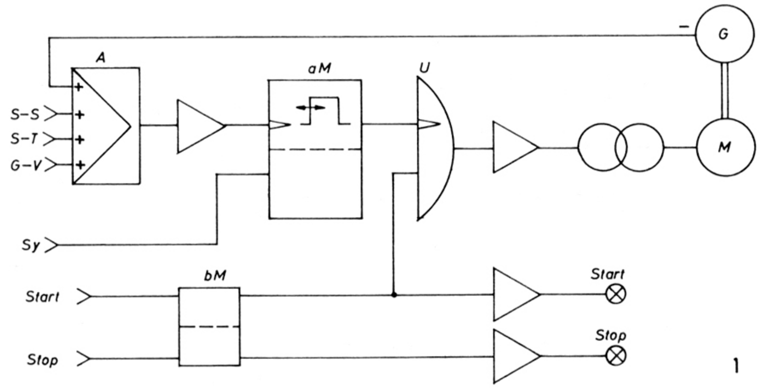
*) 16-2/3 rpm and 22-1/2 rpm turntable speeds are used for the cutting of 33-1/3 and 45 rpm records respectively when special quality demands are to be fulfilled.

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**Function schematic of the new motor control system with adder stage A, for the control voltages, the power line synchronized mono stable multivibrator aM, a bi-stable multivibrator bM and the AND-Gate U for control of the motor M.**

synchronized multivibrator (aM) stabilizes the rpm of the pitch motor (M) through use of pulse width modulation, controlled by the generator (G) running on the motor shaft. A summing amplifier (A) combines the voltages for the basic pitch (G-V) as well as the amplitude dependent variable pitch (S-S) and variable depth (S-T). The START command for the motor is given via the bistable multivibrator (bM) and the AND-gate (U).

Figure 2 shows a schematic of the control circuit. T-4 and T-5 form a multivibrator which is power line synchronized via transistor 3. The pulse width is determined by means of the network consisting of T-1 and T-2 AND the re sistors R-1, R-2 and R-3. The operating point of T-1 and T-2 is determined by the control inputs. The voltage at G-V determines the basic pitch (LPI). Input S-S feeds the amplitude dependent voltage for the space needed to accommodate the lateral groove modulation, while input S-T feeds information regarding increased groove space required as a result of increased depth cutting in stereo recording.

The rpm dependent voltage from the generator (G) is fed to R-4. The pulse width controlled square wave is obtained from the collector of T-4 and is fed to the switching transistors T-8 and T-9 after amplification through T-6 and T-7. Since the impulse rate is power line synchronized, one of the switching transistors is bridged by a diode during each half wave, while the other is conductive for a time equal to the width of the pulse.

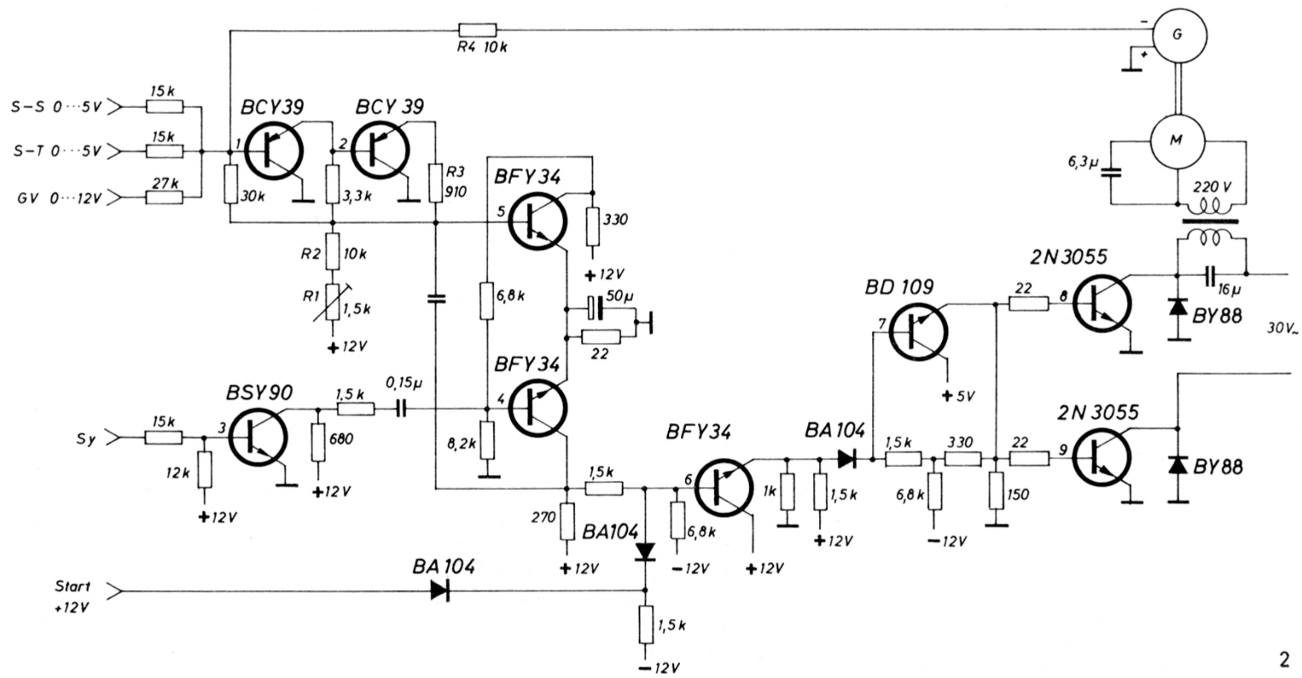
T-6 is blocked prior to the start by a negative bias of -12 V. Only after the START command connects +12 V are the square wave impulses connected to the switching transistors, and the motor runs. Any changes in the mechanical loading of the motor would cause a drop in rpm, which in turn would be compensated by the regulating loop through broadening of the square wave pulses.

A change in rpm through external influence is effected by changing the magnitude of one of the input signals G-V, S-S or S-T. This change in effect indicates to the regulating circuit a change in generator voltage, for which it tries to compensate by changing the the motor rpm, until the generator voltage compensates for the change in input voltage. Using this electronic regulating method, it is possible to obtain a stable 1:22 range in rpm.

**The Pitch Control:**

Together with the conversion of the pitch drive functions to semi-conductor circuitry, the amplitude dependent pitch and depth control amplifiers were likewere transistorized. A new control system was developed which differentiates between the various time constants associated with the left and right excursions of the groove in stereo disk cutting.

Figure 3 shows a series of grooves schematically. Groove 1 has no modulation. In groove 2 a right channel si appears. You can see that space has be provided even before the start of modulation. With the start of modulation the pitch drive can run more slowly again. Groove 3 has no modulation. Groove 4 shows the left channel modulation. In this case the basic fine line pitch can continue right to the start of

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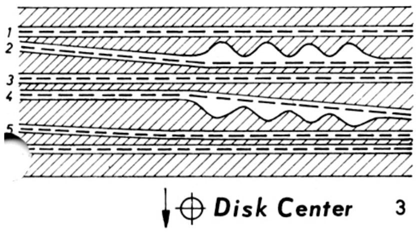
**Complete schematic of the motor control system.**

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**Cross section of 6 record grooves showing varying degrees of space required for outside and inside groove flanks.**

modulation, when increased pitch is called for to prevent overcutting of groove 5, which follows. The following empty groove 6 shows by its spacing from groove 5 the operation of the control system.

The control signals needed for variable pitch and depth control are produced in a newly devised storage system. Every quarter revolution of the turntable, a memory storage unit is charged to a voltage proportional to the maximum modulation during that part of the revolution. This voltage is stored for two more quarter revolutions, while three other memory units are charged ¼ revolution apart. The maximum value of three successive memories produces the control signal for either pitch or depth control. After ¾ revolution of the turntable, each memory is cancelled in turn, so that after a full revolution the memory is available again and the cycle can begin anew. The independent treatment of the left and right channels requires four groups of four memories each. The memory group for the control of the left flank is obtained from the playback signal, while the right flank control signal and the groove depth control, both of which take place at the same time, are obtained ½ revolution before by means of a preview head. The charging, interrogation and cancellation in proper synchronism with the turntable revolution is effected by means of a counting circuit, which gets its impulses photoelectrically from the turntable itself. As a result of the time displaced control signal starts for the left and right flanks of the groove, as well as the precise cancellation after ¾ turntable revolution, a much more efficient utilization of the playing surface of the disk results.

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