# A MECHANICAL HARMONIC SYNTHESIZER-ANALYZER

by

S. LEROY BROWN, Ph. D.,
University of Texas.

(Extract from Journal of the Franklin Institute, Philadelphia, N° 6, Dec. 1939, page 675).

The schemes that have been proposed and the electrical and mechanical methods that have been devised to aid in the processes of analysis and synthesis are so numerous that no attempt will be made to enumerate them. However, two machines have been built that warrant special mention on account of their mechanical perfection and the range of their multiple frequency components. One of these machines is the Henrici analyzer with thirty spherical integrators which was built for Professor D.C. Miller (1) at Case School of Applied Science, and the other machine is the synthesizer with forty harmonic components that was designed and built by Mr. B.E. Eisenhour (2) at Riverbank Laboratories.

The machine which is to be described herein is fundamentally a synthesizer with fifteen sine components and fifteen cosine components. The multiple ratios of the sinusoidal motions are accomplished with a train of gears of the proper ratios and the summation is accomplished by a chain and pulleys in much the same manner as is done in the tide predictor (3). The amplitude of each sine and of each cosine component may be set independently and all thirty of the sinusoidal motions are communicated simultaneously to the chain. The sum of the harmonic motions is the resultant motion of the endless chain that causes a pencil point to move in a vertical line, the pencil being fastened to a weight that is suspended from the chain. By means of a gear, rack and pinion a drawing board (in a vertical plane) is moved uniformly in a horizontal direction past the pencil point.

All parts of this machine were built on a large scale with the idea that greater precision would be had and, also, that it would be more economical to construct a large machine that is rugged and dependable even though the mechanism is rather complicated. The complete machine weighs nearly a ton; it is about fifteen feet long and seven feet high.

*Details of the Machine.* — The driving mechanism is a train of twenty-two spur gears that are high grade but selected from commercial stock. These gears drive fifteen shafts with rotational ratios ranging from one to fifteen. A Scotch crosshead is operated from each end of each shaft with the pin of each crosshead set in quadrature with the pin of the crosshead at the other end of the respective shaft. As the pin of each crosshead executes uniform circular motion it transmits sinusoidal motion to a vertical rod (in guides), and near the top of each vertical rod there is a small pulley over (or under) which passes a fine chain. The sum of the thirty sinusoidal motions is communicated to a tracer point (pencil) by means of the pulleys and the continuous fusee chronometer chain. The motion of the pencil point is in a vertical line and the pencil is carried by a metal block (in guides) that is suspended by the chain. By means of a rack and pinion, one shaft of the gear train drives the drawing board (in a vertical plane) with uniform horizontal motion past the pencil point. The rack is adjustable to different sized pinions and, thereby, the wave-length of the curve traced on the drawing board may be adjusted.

A front of the machine shows the eccentrics that furnish the fifteen sine components, the tracer block that is suspended by a loop of the endless chain around a pulley on the block, the drawing board, and the crank by which the train of gears is driven.

A back of the machine shows the eccentrics that furnish the fifteen cosine components. The chain threads around the pulleys on the vertical rods, it is transferred from front

(1) D.C. Miller, Jour. Frank. Inst., 182, 285-322.

(2) Frederick W. Kranz, Jour. Frank. Inst., 204, 245-262.

(3) Special Publication N° 32, U.S. Coast and Geodetic Surey, Washington, D.C.

to back and from back to front over stationary pulleys, and tension is maintained in the continuous chain by the weight of the block that carries the tracing point. A more uniform tension is maintained throughout the length of the chain by subjecting the entire machine to slight vibrations. The vibration of the machine is produced by a small electric motor with eccentric shaft and this method of reducing friction might be termed "mechanical lubrication".

The pin of each crosshead may be slid in either direction from a center-position on a crossbar and, thereby, positive or negative amplitudes are possible. The greatest amplitude that may be set on the fundamental is 16 cm. and the crossbar of a fifteenth element is long enough to permit amplitude settings of as much as 4 cm.