AIRBORNE CONTROL LABORATORIES
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APALACHIN, NEW YORK

INTRODUCTION

The ACL Mark II consists of a transmitter, a superheterodyne receiver and three servo actuators which are mounted as an integral part of the receiver.

The Mark II is designed to simulate full-scale flight characteristics as closely as possible. A single control stick, mounted on the front of the hand-held transmitter, provides control of the rudder and elevator. An engine control toggle switch mounted on the side of the transmitter provides trimmable engine speed control. Trim knobs located at top, for the rudder and side, for the elevator, allow inflight trim of the rudder and elevator to accommodate changes in fuel load and the like.

The airborne unit contains a crystal controlled superheterodyne receiver to minimize interference, and the control circuits required to operate the built-in servo actuators. All critical circuits are transistorized. The system is completely pre-tuned. The power converter for the transmitter is included in the transmitter.

The system has been tested over the temperature range of 0°F. to 130°F.

The Mark II features proportional, independent simultaneous control of the rudder and elevator with trim control of the engine speed. The servo actuators are of the feedback design so that full thrust of 2 pounds is achieved, the return to neutral is positive and precise and there is no wiggle of the control surfaces. A failsafe circuit is included so that in the event the signal from the transmitter is lost, the servos will return to neutral and the engine will move to the low speed position.

PROPORTIONAL CONTROL

Before discussing the details of the ACL Mark II proportional control system let us first consider the how and why of proportional control.

Proportional control means just that; the motion of a particular surface of the aircraft is proportional to the motion of the control stick (as with a full scale aircraft) and the neutral position of the surface is determined by the neutral position of the control stick. For example, if the flyer moves the control back to a 1/2 up position, the elevator will move to the corresponding 1/2 up elevator position. This will be true regardless of the speed of the aircraft. There is no surface blowback with a true proportional system. The surface will remain in this position as long as the flyer maintains that particular stick position. When the stick is returned to neutral, the surfaces will also return to neutral. True proportional control depends upon capability of the servos which drive the flying surfaces.

Historically, proportional control has been attempted with many types of servos with little real success until the development of the feedback servo. Most early servos depended on some form of spring centering to obtain the proportional action. Those servos had to overcome the centering spring torque as well as the force of air against the flying surface. Since available torque was limited, the result was surface position which was dependent on aircraft speed as well as the input signal to the servo. Surface blowback was a major disadvantage because of spring centered servos. In general, early servos exhibited low torque, high current drain and an unsightly tendency to wiggle.

With the feedback servo, the proportional action and centering is accomplished electronically rather than by use of centering springs. Thus, the feedback servo has overcome the major disadvantages of the early proportional servos. High torque (1 inch pound or more) at an average current drain of 40 milliamperes or less is achieved. In addition, the feedback servo is smaller and lighter than its historical predecessors.

The achievement of true proportional control through the use of the feedback servos and the advantages of high torque, low battery drain, light weight and no surface wiggle is the key to the fine performances of the ACL Mark II proportional control system.

THE ACL MARK II

The ACL Mark II is designed to give proportional, simultaneous, and independent control of the rudder and elevator with trimmable engine speed control. Proportional aileron control can be achieved by either electronically coupled (with an additional servo) or mechanically coupled aileron and rudder (C.A.R.).

The Mark II consists of two basic parts: 1) the hand held transmitter which contains the power supply, the pulser, tone generator and r.f. section and, 2) the airborne unit which contains the superheterodyne receiver, the control electronics, the two proportional servos, the failsafe circuit and the engine speed control servo.

The control functions for rudder, elevator and engine in the ACL Mark II originate in the hand held transmitter. The rudder and elevator functions are controlled by the control stick which is capable of right-left and up-down motion as desired. This stick is centered by coil springs to give a "feel" for the motion of the stick, and positive return to stick neutral. In addition to the control stick,

there are trim functions for both the rudder and elevator to allow for inflight trim of the flying surfaces about neutral to accommodate changing fuel load and slight lack of aerodynamic trim of the aircraft.

Engine speed control is accomplished with the double throw momentary toggle switch located on the side of the transmitter. The engine speed is trimmable in either direction by moving the toggle switch forward or backward. A neutralizing function in the airborne unit neutralizes both proportional servos during engine speed changes so that there is no significant change in the attitude of the aircraft while changing engine speed.

The Mark II is a flexible design and has major advantages for all types of flying. In general, the superhet receiver provides protection from interference problems and allows simultaneous flight with other aircraft with superhet receivers (on different frequencies). The in-flight trim functions are of great advantage. To many, the fact that the Mark II is completely pre-wired, factory tested and contained within a single unit is a real benefit. Installation in an aircraft now becomes a matter of mounting, connecting the batteries and the push rods. No servos, receivers, or the like to mount separately and wire.

Class I For the larger rudder only airplane it is possible to achieve proportional rudder control and trim engine control. If the rules permit, the elevator servo can be used to achieve proportional engine speed control. The light weight of the airborne unit and battery supply, plus the proportional control and inflight trim functions offer many competitive advantages.

Class II With or without coupled aileron-rudder (C.A.R.) the Mark II is a real competitor in Class II. In addition, the high torque of the feedback servo will allow a steerable wheel coupled to the rudder servo. The result is a full performance aircraft which will give outstanding flight characteristics.

Pylon Race Here is the real test for any control system. Working against time, the need for a smooth flight is paramount. We firmly believe that all else being equal, proportional control will produce the smoothest flight. The serious competitor will want minimum equipment weight and by removing the engine servo (this is easily done) the weight of the Mark II airborne unit is reduced to 11-1/2 ounces.

Scale Having devoted the time and energy to reach new heights of perfection in his scale aircraft the scale flyer is concerned with that critical first flight. Here, all can be lost if the aerodynamic trim is incorrect. The Mark II offers a real advantage, first because proportional control will allow the necessary correction and secondly because the inflight trim can accommodate the oddities of this first flight until a safe landing is accomplished. In addition, the scale flyer seldom has time to make lengthy equipment installation. The ease of installation of the single Mark II airborne unit greatly simplifies this task.

Sports Flying Many of us still fly just for the fun of it. The Sunday flyer will find that the Mark II meets his needs for ease of installation, ease of flying, realism of flight and sheer enjoyment. The advantages listed for the various competition classes certainly apply for Sunday flying, but perhaps most important is flying ease. With or without coupled ailerons, the ease is there: one stick control without the needs of thumb dexterity or coordination. Simply move the stick and watch the aircraft follow!

OPERATION AND SPECIFICATIONS

In the pulser section of the transmitter a series of pulses of variable on/off ratio and rate are generated. A particular on/off ratio and a particular pulse rate correspond to the neutral position of the rudder servo and elevator servo respectively. Changes in either the on/off ratio or the pulse rate will cause a corresponding change in the position of the rudder or elevator servos after this information has been transmitted to the aircraft, received, and the necessary conversion has been made. Since the change in on/off ratio is a linear function of the right-left position of the control stick, the rudder is thus proportionally controlled by the position of the control stick. The same is true for the pulse rate, the up-down position of the control stick, and the elevator servo.

Transmitter The signal in the pulse generator starts at the saw tooth wave generator. The repetition rate of the saw tooth wave is controlled by two potentiometers: the elevator stick pot and the elevator trim pot. The elevator trim knob is located on the side of the transmitter and the rotation direction corresponds to the direction of stick motion.

The saw tooth which is rate variable is then clipped at a height determined by the rudder stick control (or rudder trim control) to produce a variable on/off ratio. This signal is then converted to a square wave which has variable on/off ratio as determined by the rudder stick pot and the rudder trim pot, and variable rate as determined by the elevator stick pot and the elevator trim pot.

A motor control toggle switch is located on the side of the transmitter case. Motion in the forward direction will produce higher engine speed (full on) in the backward direction will give lower engine speed (full off).

The control stick is mounted on the transmitter case at the upper right-hand corner. The stick is spring centered to return it to the neutral position and to give a "feel" for the aircraft. The trim knobs are mounted convenient to either hand so that inflight trim can be easily accomplished.

The signal from the pulse generator keys an audio tone generator. This tone generator frequency matches the audio frequency of the control circuit in the airborne unit. This tone generator frequency is stable over the normal operating temperature range (0° F. to 130°F.). The transmitter is of conventional design. The power input to the r.f. amplifier is approximately 2 watts. The antenna is fed by a pi matching network for maximum efficiency. The antenna is a telescoping 54 inches long when extended and 3 inches when collapsed.

Power for the pulse and tone generator and the r.f. portion of the transmitter is supplied by a built-in DC to DC converter. This converter requires a 6 volt input. Recommended battery complement is 5 "D" size nickel cadmium cells (approximately 4 ampere hours capacity). With the recommended battery complement, better than 4 hours of continuous transmitter operation is possible between recharges.

Specifications: Transmitter

- 11 transistors, 3 tubes, 6 diodes
- measures 9-1/2 x 6 x 3-1/2
- pulse rate 20 to 50 pulses/second
- on/off ratio 80/20 to 20/80
- audio frequency 3700 cps ± 300 cps nominal

- filament voltage 6 volts
- B + 150 volts @ 22 milliamperes
- input voltage 6 volts D.C.
- input current 900 milliamperes

Airborne unit The receiver in the ACL Mark II airborne unit is the ACE R/C KHFE* crystal controlled superhetrodyne receiver complete through the I.F. stages and diode detector. The receiver is packaged separately and mounted on the airborne unit circuit board by means of rubber vibration mounts in a fashion similar to the servo mounting. The signal from the receiver is amplified and fed to an audio frequency selective reflex switching circuit.** The transistorized switch is on with full tone and off with no tone. It responds to the 3700 cps ± 300 cps tone, but rejects noise and tones of any other frequency. The output of the reflex switch is a square wave which is a replica of the signal out of the transmitter pulse generator. The rate and on/off ratio is a function of the rate and on/off ratio at the pulse generator. The process of generation-transmittion-reception-reconversion is now complete. This square wave controls directly the rudder servo in that if the signal is on more than off, rotation of the rudder servo will tend to produce a right turn, conversely if more off than on rotation will be toward the left. Equal on and off w ill result in a neutral position.

The square wave signal is also fed to the rate computer which serves to generate a square wave on/off ratio which is a function of the pulse rate. This is done by a single shot multivibrator triggered by the leading edge of the input square wave. Since the single shot remains on for a fixed period of time, and is off for a time depending on the pulse rate, the output is a square wave of fixed on time and variable off time giving a variable on/off ratio. This signal is fed to the elevator servo which responds in a similar fashion to the rudder servo.

The signal from the reflex switch is also fed to the fail-safe and engine control circuit. This circuit is basically a delayed trigger circuit and is normally off during pulsed input conditions. There are two sections in this circuit, one which operates when the reflex switch has been on for greater than about 20 milli-seconds, the other which will operate if the reflex switch has been off for this period of time. These circuits will drive both the engine control servo (in either direction dependent on whether the condition is on or off) and the neutralizing or failsafe circuit.

The feedback servos are the key to the performance characteristics of the ACL Mark II. The operation of a feedback servo is based on the ability of the servo amplifier to compare the position of the servo output arm (hence the control surface) with the input signal which contains the positional instruction and to respond to any differences. For example, if the on/off ratio is signaling 1/3 right rudder (1/3 stick motion at the transmitter) the amplifier compares the position of the servo output arm with this signal and if the servo is not at the 1/3 position it will move until it reaches this position. If it were already at this command position, there would be no motion required of the servo and it would remain stationary at the 1/3 position. Thus, centering and position are electronic, and there is no flop or

* The KHFE is a Kraft product sold by ACE R/C, Inc.
** John Phelps - Syracuse, N. Y.

pulsing of the servo. In addition, the current drain by the servo motor is negligible except when the servo is moving to a command position.

Electrically, the feedback function is accomplished by attaching a potentiometer to the servo output shaft which provides a voltage level proportional to the position of the shaft rotational position. The voltage level at the potentiometer is compared to the input command voltage by a differential amplifier. The difference signal, which can be either positive or negative is amplified and fed to the servo to drive the motor either positive (to the right) or negative (to the left). In the Mark II, the feedback potentiometer is a miniature wire wound potentiometer to insure long life and reliable operation.

Specifications: Airborne unit

- crystal controlled superheterodyne receiver
- tone selective reflex switch - 3700 cps ± 300 cps nominal
- failsafe circuit
- 26 transistors, 6 diodes
- 2 feedback servos
- 1 trimmable engine control servo
- measures 6-3/4 x 2-3/4 x 2-1/2
- weight 14 ounces
- servos - require 4 "AA" size nickel cadmium cells
  current drain - 80 milliamperes average
- receiver - requires 9-volt dry cell
  current drain - 4 milliamperes
- battery requirement - 4 "AA" size nickel cadmium cells (500 mah)
  1 9-volt dry cell
- switch requirement - 3 pole (total) on/off (may be switched in any order)
- feedback servos - 6 transistors
  wire wound feedback potentiometer
  torque - 1 inch pound
  thrust (1/2" arm) - 2 pounds
  current drain - 40 milliamperes average
  voltage ±2.4 volts
  rotation ± 45°

RELIABILITY

In addition to fine performance characteristics of the Mark II, the reliability of the system is outstanding. The high level of reliability is achieved both by the design and the manufacturing controls.

The design, selection of components and manufacture of the Mark II is under the constant supervision of an experienced Reliability Engineer. This supervision and the quality control procedure assures a unit produced in keeping with today's standards of excellence.

GUARANTEE

The ACL Mark II is designed and tested to insure long life and trouble-free use. As with any complex electronic and mechanical system, an occasional defect can occur and the unit is protected by our guarantee:

The ACL Mark II is guaranteed against defects in material and workmanship for a period of 90 days from the date of purchase. This guarantee is void for damage caused by misapplication, misuse or by non-authorized repair. Both the transmitter and the airborne unit must be returned if service is necessary to either one.

ORDERING

The Mark II is available as a complete system. All that is required in addition, is the batteries and switches. All plugs, charging jacks, wire and cases are included. The list price of the Mark II is .....$299.95.

All units are wired to accommodate an electronically coupled aileron servo. While mechanically coupled ailerons work equally as well, the electronic coupling is somewhat easier. List price for the aileron servo is .....$37.50. (Specify on order if desired.)

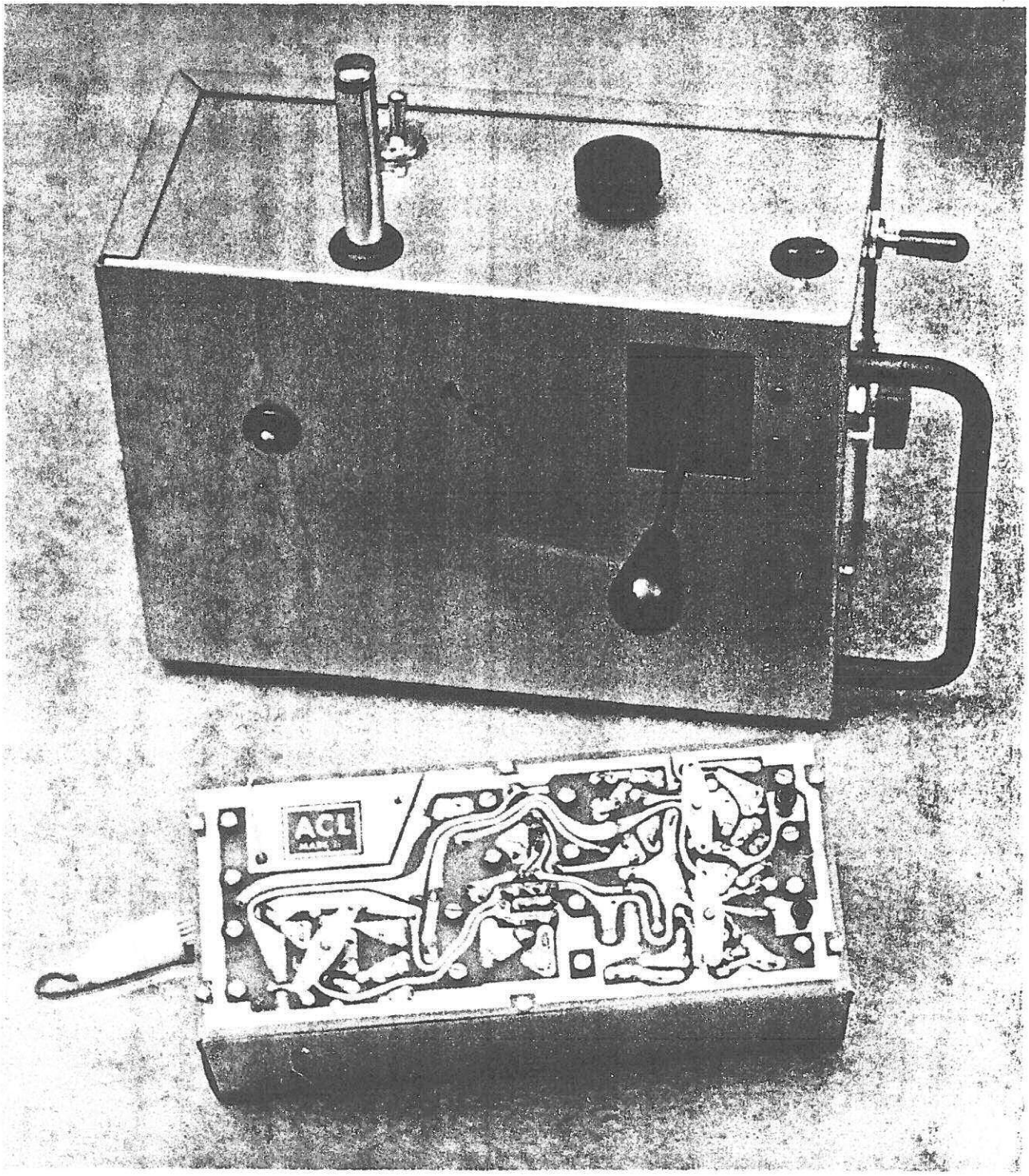
More than one airborne unit may be operated from a single transmitter, and additional airborne units may be purchased. The list price for an additional airborne unit (complete less batteries) is .....$169.95.

Delivery is within 6 weeks A.R.O.

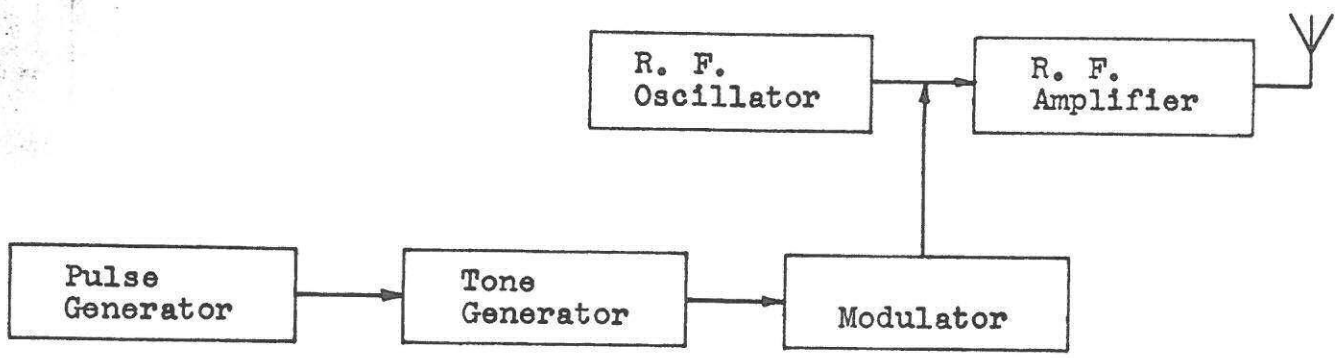
Terms are prepayment in full with the order. Your prepayment will be held in escrow by ACL until 10 days prior to shipment.

You may order direct from the factory, or through your dealer. Send orders to:

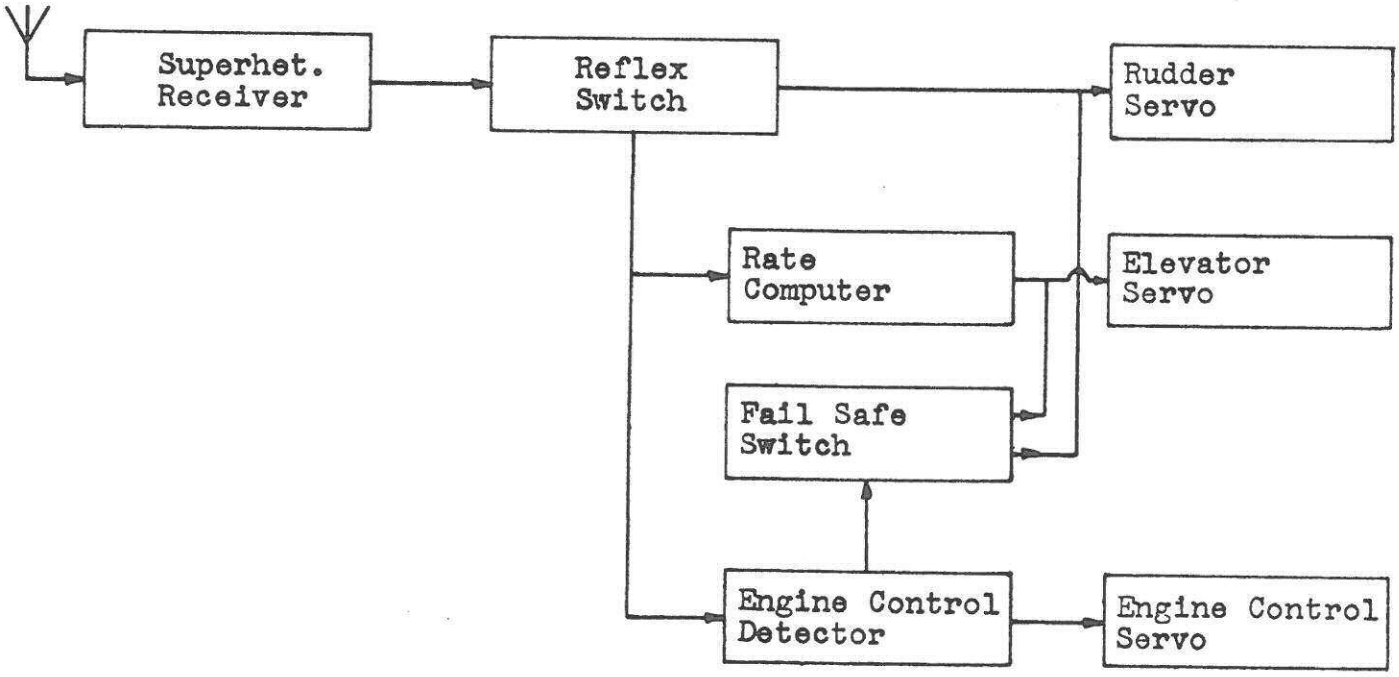
The Airborne Control Laboratories
49 Glann Road
Apalachin, New York



MARK II

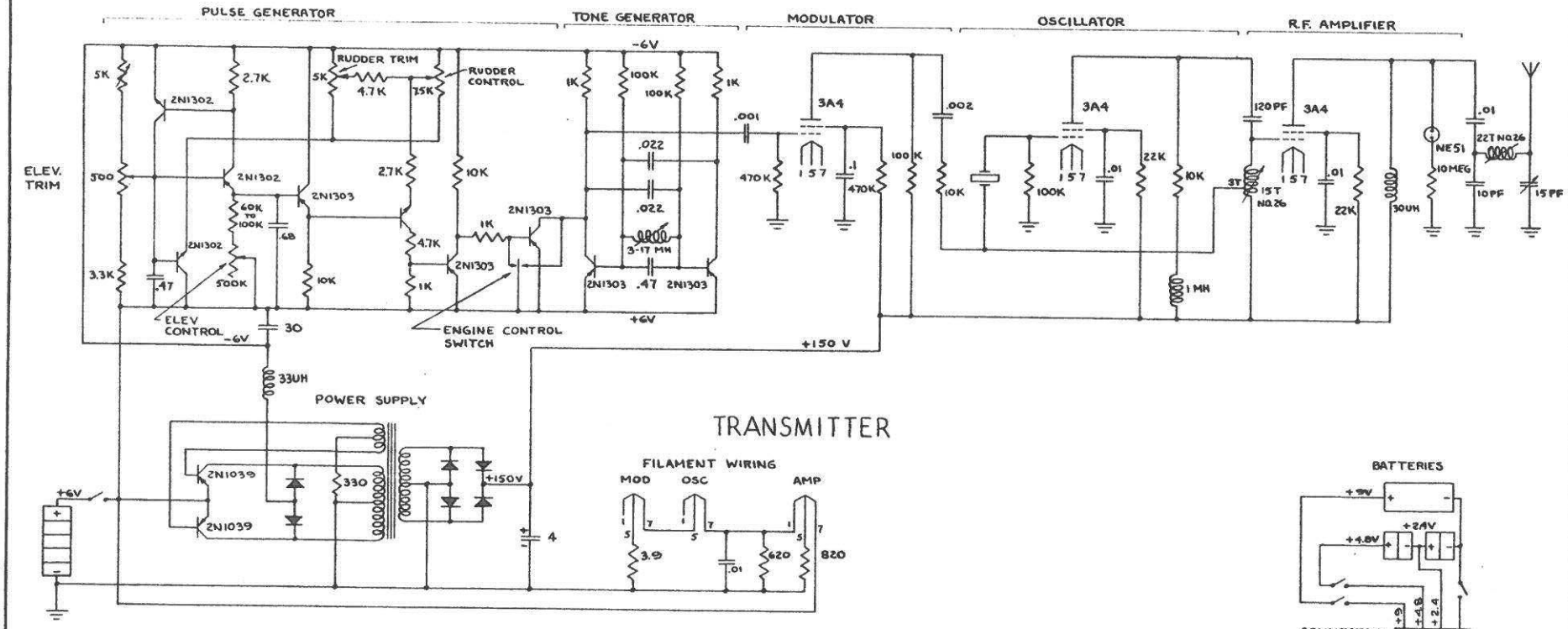


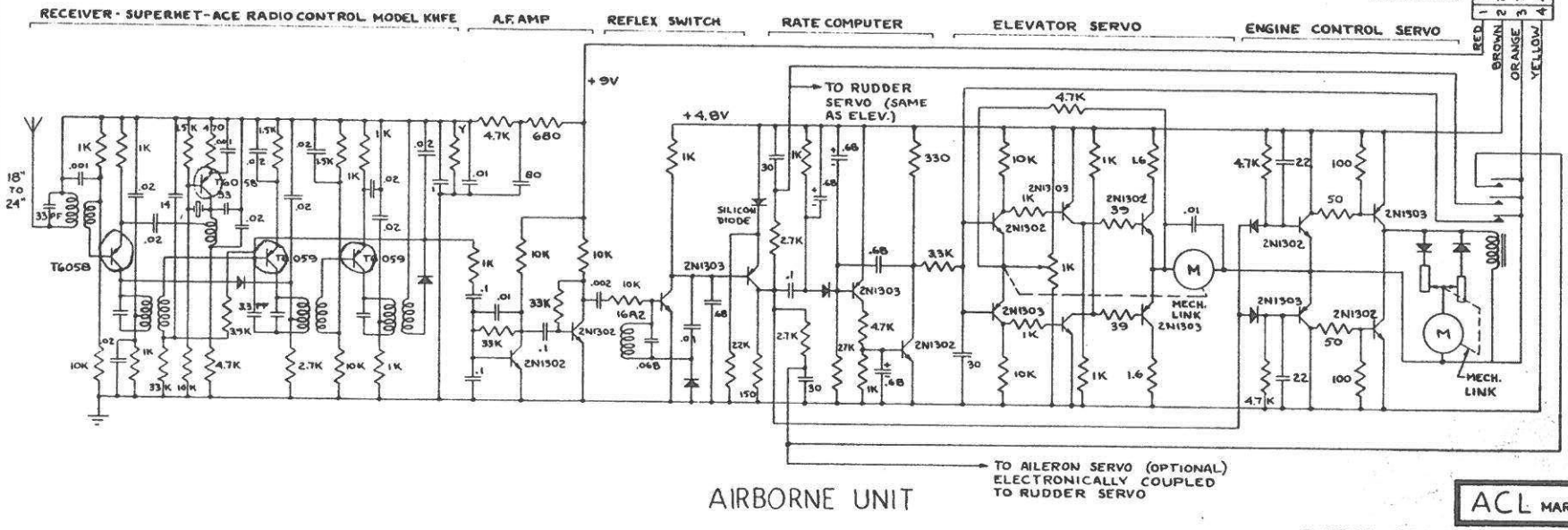
TRANSMITTER



AIRBORNE UNIT

ACL Mark II
Radio Control System



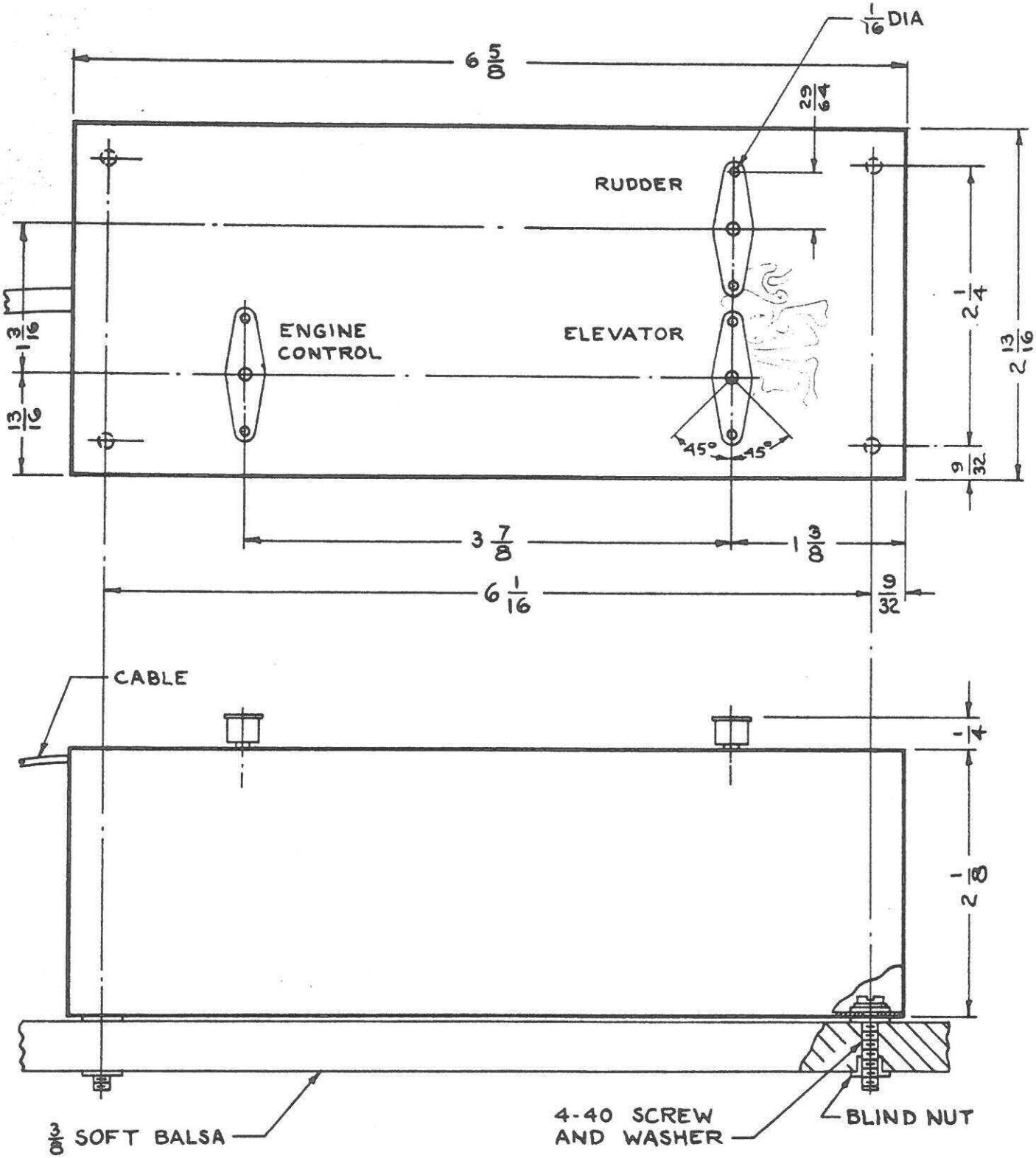


ACL MARK II

RADIO CONTROL SYSTEM

DECEMBER 14, 1962 EJ

AIRBORNE CONTROL LABORATORIES, 49 GLANN ROAD, APALACHIN, N.Y.



NOTE:
SERVO POSITIONS ARE INTERCHANGEABLE

INSTALLATION DIAGRAM

FOR AIRBORNE UNIT