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FABRICATION AND TEST OF MODIFIED QUADRUPOLE MASS
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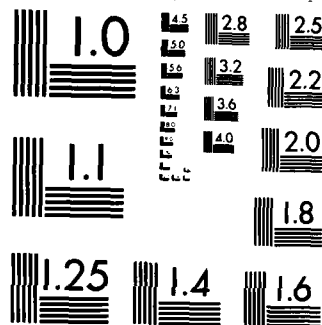
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AFGL-TR-85-0002

MODIFY FABRICATE AND DELIVER ELECTRONICS
FOR A QUADRUPOLE ION/NEUTRAL MASS SPECTROMETER

C. G. KUCZUN

TRI-CON ASSOCIATES, INC.
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Cambridge, MA 02138

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HANSOM AFB, MASSACHUSETTS 01731

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This technical report has been reviewed and is approved for publication.

Edmund Trzcinski
 EDMUND TRZCINSKI
 Contract Manager

William Swider
 WILLIAM SWIDER, Acting Chief
 Ionospheric Disturbances Branch

FOR THE COMMANDER

Robert A. Skrivaneck
 ROBERT A. SKRIVANEK, Director
 Ionospheric Physics Division

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I INTRODUCTION

The objective of this contract was to modify, fabricate, test, and deliver the electronics for a quadrupole ion/neutral mass spectrometer capable of making positive ion and neutral species measurements over a range of 1 to 70 atomic mass units (AMU) with a mass sampling rate of 100 per second and consisting of the following subassemblies.

Power Supply - Schematic D-2030;
Layout D-2031.

Command Relays and Switched Bias Amp -
Schematic D-2036; Layout D-2037.

Sweep Amp and Data Multiplexer -
Schematic D-2042; Layout D-2043.

Program Card - Schematic D-2044;
Layout D-2045.

Electrometers - Schematic D-2053;
Layouts C-888 & C-889.

RF Oscillator - Schematic C-857;
Layout B-860.

Electronics Box - D-2028 and Wiring
Diagram D-2047.

These subassemblies are to be fabricated to the existing manufacturing drawings indicated with minor modifications developed in the work done previously.

In addition, the Emission Regulator which exists presently as Schematic D-2034; Layout D-2035, has been redesigned as detailed in Paragraph II.

II EMISSION REGULATOR

The collected electron beam current can be set at any level between 50 μ a and 120 μ a and remain in regulation over a pressure range of 10^{-8} to 2×10^{-4} TORR water vapor with no oscillation.

The new Emission Regulator design is represented by Figure 1 - Block Diagram and the card detailed Schematic D-4065. The circuit has been bread-boarded by using a 6AL5 electron tube to simulate the emission chamber represented by the filament and anode in the actual quadrupole.

The approach is to incorporate a built-in hysteresis or dead zone by use of two thresholds whose references are separated by a voltage difference plus a digital counter as control signal storage in the loop. Referring to Figure 1, the action is as follows:

The electron beam current collected is voltage converted by operational amplifier A_1 into E_o as shown. This output is applied to opposite sense comparators C+ and C-. For any output level E_o less than T+ or greater Than T- there is no action.

Outside their limits one of the comparators changes state and through the OR gate enables the free running oscillator OSC. The output of this OSC triggers the up-down counter U/D in a direction determined by which comparator's threshold has been exceeded. The change in state of U/D stages are converted into an analog signal by a D/A converter (after going through level changing and into a different ground system via optical isolators O/I). This changed analog signal E_c is used to control the output of a switching regulator S/R which in turn controls the filament converter and the power to the filament. This change in filament power is such as to change E_o and bring it back into the dead zone between the two thresholds $T+$ and $T-$ of the comparators $C+$ and $C-$ and thereby inhibiting the OSC and stopping the action. If the disturbing error is so great that a single change in state of U/D does not make E_o reach the dead zone between $T+$ and $T-$ then the OSC continues pulsing and advancing counter U/D in the direction required until this occurs.

The advantages of this technique are as follows: At power turn-on the up-down counter would be preset in the middle of its range and the system would start close to original calibration setting in the laboratory or that determined by some previous command.

Every time an input error results in a violation of the hysteresis represented by the thresholds $T+$ and $T-$ the correction is made in successive small signals by the up-down counter U/D. The rate of these corrections is determined by oscillator OSC. This rate is purposely made slow enough so that after each step correction the complete system has reached equilibrium and all transients, overshoots, etc., are over. for example, in order to accommodate the thermal time constant of the filament (T) the equilibrium conditions realized as a function of the oscillator rate would be:

nT	% Correction
1	37%
2	14
3	5
4	2

Therefore, for a filament thermal time constant of 100 milliseconds a specification of 2.5 Hz on the OSC rate would permit the system to stabilize to within 2% of the asymptotic of the emission.

The dynamic range limits on the filament drive are automatically and linearly controlled by the fact that up-down counter would not be permitted to roll over in either direction and the control

signal E_c would be limited by the D/A gain control R_3 . This feature would inherently prevent the possibility of burning out the filament. The switching regulator S/R and the filament regulator would never be coming out of hard-on or hard-off conditions as a function of large input errors.

The setting of the electron beam current is easily set by means of the offset control R_2 in the current amplifier A_1 circuit. For any nominal current I_0 desired, R_2 is set so that E_0 equals zero for that current. By means of latching relays this could be changed by on-board programming or indirect command functions.

The magnitude of the hysteresis or dead zone is established by adjustment of gain of the current amplifier with R_1 and the settings of thresholds $T+$ and $T-$ of comparators $C+$ and $C-$. For example a ± 5 microamp hysteresis would result with thresholds of ± 1 volt and R_1 equal to 200K. These parameters could also be set in the lab or by programming or by command.

There is an optimum relationship between the comparator threshold and the single bit change in the up-down counter and therefore the incremental change in E_0 . That incremental change ideally would be the threshold voltage T . Too large an

increment would result in a one bit oscillation rate of OSC. Too small an increment would result in possible increase of the hysteresis or dead zone and therefore reduction in dynamic accuracy. Neither of these conditions is critical.

The capacity of the up-down counter is somewhat arbitrary but it does affect the dynamic range. For example: if the nominal emission current I_o is equal to 100 microamps, the dynamic range versus dead zone and counter capacity is:

I_o Microamps	Dead Zone $\pm$ Microamps	Counter Capacity	Dynamic Range
100	1	16	92-108
100	2	16	84-116
100	5	16	60-140
100	1	32	84-116
100	2	32	68-132

However the use of a counter capacity of 16 is desirable, in that an up-down counter of that capacity comes in a standard single DIP pack.

The enabling - inhibiting of the stepping oscillator OSC could be done two different ways. One would be to advance the up-down counter the moment either comparator threshold was exceeded and then

advance it at the natural rate as long as the threshold is exceeded. The other way would be to delay the triggering for one-half the OSC interval after the threshold is exceeded and then at the natural rate. The former is sort of a fast response time enhancement. The latter is sort of a built in delay to minimize reaction to rapid but short disturbances. The OSC rate can easily encompass the range from 100 KHz to .01 Hz or for practical and useable interval limits of 100 seconds to 0.1 second.

The hardware required over and above used in the present systems would be quite nominal. Assuming a four bit up-down counter which is one DIP package: the current amplifier, two comparators, and the oscillator could all be designed around a quad operational amplifier chip. The OR gate could be diodes. The optical isolator is a single DIP package, and the D/A converter could be synthesized with resistors.

In the final circuit represented by D-4065, the winding 4-5-6 on T_1 which develops approximately 5 volts as $H +$ is used as the input to the switching regulator, U_6 (National LH 1605CK). The emission current collected at the anode is amplified by U_4A (OP420). Its gain is controlled by selection of R_{50} and the amplifier offset is determined by R_{22} . Zeners CR_{14} and CR_{15} are used to prevent saturation

of U_4A which would essentially open the loop around U_{45} . U_4B is a non-inverting buffer and U_4C is an inverting buffer. U_5A and U_5B are sections of a LM 139A quad-comparator. They are operated as combination threshold comparators and oscillators. When either threshold is exceeded it generates pulses to drive the Up-Down Counter U_8 (RCA CD 40193B) in the proper direction to reduce the emission current error such that it is less than the positive threshold and greater than the negative threshold. The 4 binary bits of the counter (Q_1, Q_2, Q_3, Q_4) drive the 4 bit optical isolator U_7 (HP 6N140). The outputs of the optical isolator are A to D converted at the floating filament supply level (F-) by the binary weighted resistors $R_{28}, R_{29}, R_{30}, R_{31}$ and this is used as control load for the switching regulator U_6 .

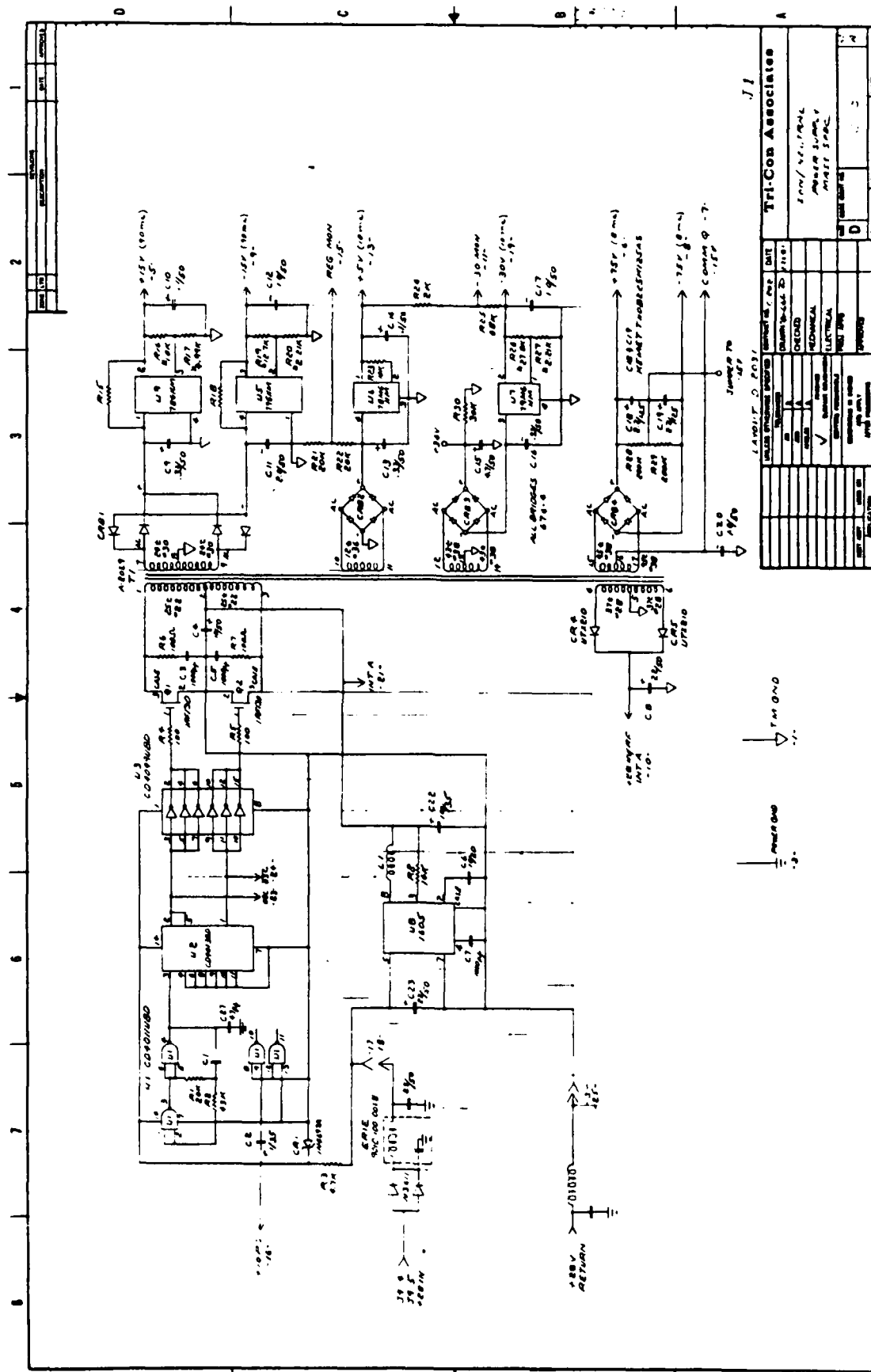
Two AND gates represented by the 4 diodes of U_9A and U_9B are used to detect the limits of the binary counter U_8 and thereby prevent the thresholds from being exceeded any longer and rolling over the counter.

III TEST CONSOLE

A test console is supplied with the mass spectrometer electronics to allow for field test without the need of a large number of test instruments.

The test console will supply the power and timing functions and display mode and data signals received from the experiment.

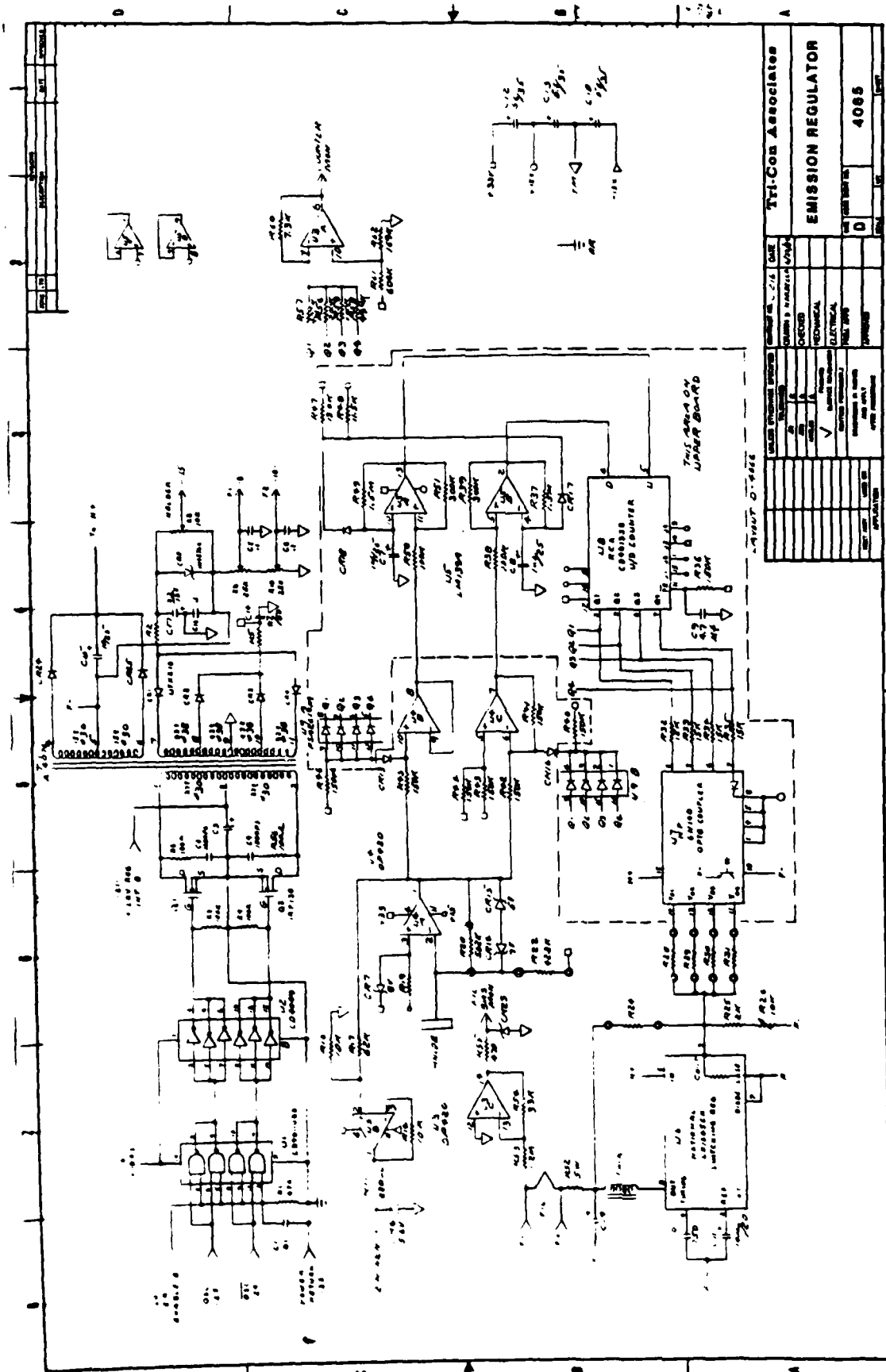
Auxiliary jacks are available to allow for more precise measurements of each parameter.



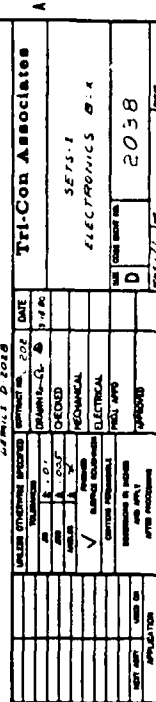
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CHECKED BY	W. J. JONES
APPROVED BY	W. J. JONES
TESTED BY	W. J. JONES
REVISIONS	
NO.	1
DATE	10/1/74
BY	W. J. JONES
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