FAIRCHILD

CAMERA AND INSTRUMENT
CORPORATION

FCI-19-94(2-62)

YOUR NOTEBOOK

1) This notebook is a record of your thought and activity as an engineer and employee of Fairchild. Its contents must be safeguarded as "Company Private Material", and shall not be disclosed to anyone outside of the Fairchild Organization without proper authorization. All notebooks are the property of Fairchild and shall be turned in to the Notebook Registrar upon termination of employment.
2) Material selected for invention disclosure must be submitted to the Parent Company Patent Department in accordance with SPI-19-405.3. If you do not have a copy of this instruction see your supervisor.
3) The procedure below specifies how notebooks must be maintained to make them acceptable in patent proceedings as legal proof of what was done and when it was done. The early date of record may be the deciding factor in obtaining an important patent for Fairchild in your name.
4) Proper maintenance of your notebook is a meaningful contribution to your individual progress at Fairchild.

NOTEBOOK ENTRY PROCEDURE

1) Make regular entries in this notebook of all notes, calculations, sketches, circuit diagrams, formulas, equations, graphs, developmental and test observations, and all test results and conclusions regardless of whether successful or not. (DO NOT USE SCRAP OR OTHER LOOSE PAPER FOR THIS WORK.)
2) All entries shall be kept chronologically using a separate page for each idea and all entries on any one page shall be made only as of a single date indicated on the page. Draw lines through unused portions of a page so there are no empty spaces between entries. (DO NOT SKIP PAGES AND NEVER TEAR OUT PAGES.)
3) Do not make entries in the notebook of another and do not permit anyone to make entries in your notebook.
4) When blueprints, photostats, or other material will clarify or explain entries, affix such material securely to the appropriate pages.
5) New ideas which may be original regardless of whether they are conceived under company sponsored program or a commercial or government contract should be entered in sufficient detail to enable any engineer or any person skilled in the art to fully understand the idea involved. Such entries should be dated and attested by two individuals who have read and fully understood the entry. (DO THIS PROMPTLY.)Subsequent additions or changes should be made on other pages likewise dated and attested and reference previous pages and earlier notebooks.
6) If the new idea has been operated in a piece of apparatus your notes should include a description of the conditions under which the apparatus operated, the operations performed, the persons present, the data taken and any other facts which will substantiate the steps taken by you. Two engineers, one preferably your supervisor, should witness such apparatus operation, check the detail sufficiently that they know the idea embodied therein and sign the notebook pages as having witnessed the operation. At this point check with your supervisor if the apparatus is to be tagged and stored as a patent exhibit.
7) Take your notebook to conferences or technical discussions and enter any ideas or suggestions you make, refer to the discussion, those present and its date. Shortly thereafter, amplify the notes so they will be understandable at a future date. Obtain signatures of two witnesses who were present when the disclosure was made.
8) By following the above instructions you should always be able to testify that any one of your notebook pages is in its original condition and that no changes were made thereto after the original entry and signatures.
9) When inventive work is performed under a Government Prime or Subcontract which is classified for security purposes, a separate notebook shall be kept for each such contract and the notebook shall be safeguarded in accordance with requirements applicable to the security classification of the contract.

NOTEBOOK CONTROL PROCEDURE

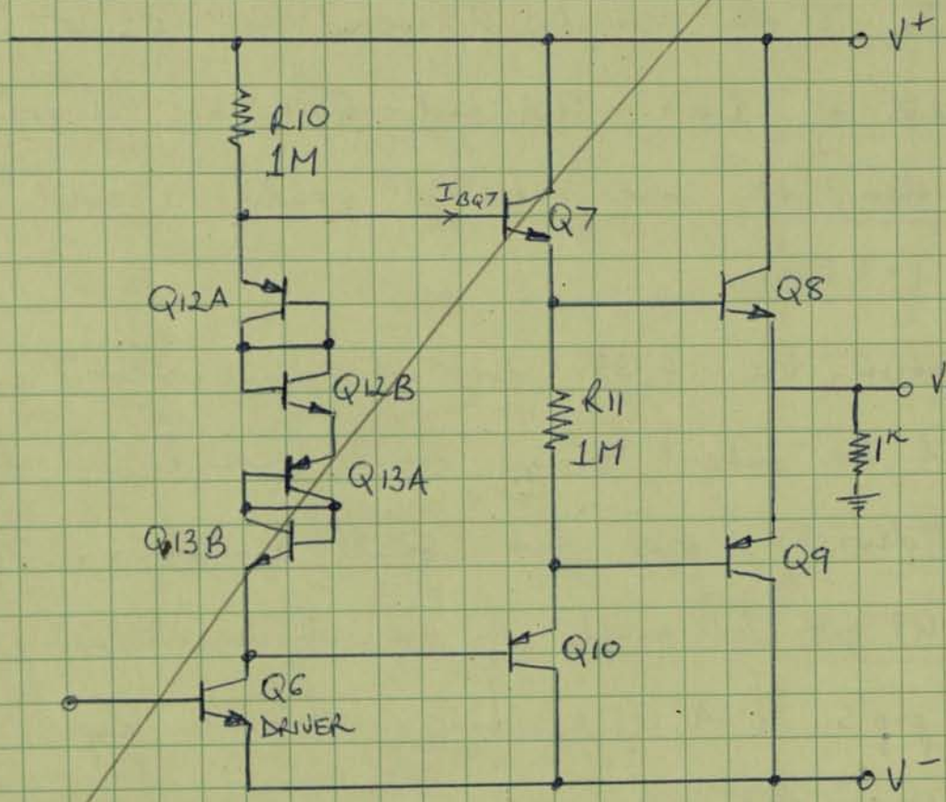
1) Each notebook issued shall have a copy of this instruction affixed to the front inside cover.
2) Each notebook page shall be numbered and the book itself shall be numbered and recorded by employee name in a register maintained by each Engineering Department.
3) Each notebook shall be periodically reviewed by the employees supervisor.
4) Each filled notebook that has served its reference use shall be returned to the notebook registrar for filing.

Lab Notebook # 586.

George Erdi

A NEW OUTPUT STAGE FOR MICROPOWER OPERATIONAL AMPLIFIERS

The limitations of present micropower output stages are best understood by considering the output stage used in the μA735



μA735 output stage

The maximum output swing one can obtain is

$V^+ - I_{BQ7} - V_{BEQ7} - V_{BEQ8}$ positive swing

$V^- + V_{sat\ Q6} + V_{BEQ10} + V_{BEQ9}$ negative swing

Since $V_{BEQ7} + V_{BEQ8} \approx V_{BEQ10} + V_{BEQ9} \approx 1.7$ V at −55°C, the best swing one can expect is ±200 mV with ±2V supplies, the circuit cannot be operated with ±1.35 V supplies.

Statement of Operation NEW OUTPUT STAGE FOR MICROPOWER OPERATIONAL AMPLIFIERS

Witnessed operation (obtain two signatures):

Signature _____ Date _____

Signature _____ Date _____

Signature George Erdi Date April 9 1969

Read and Understood (obtain two signatures):

Signature _____ Date _____

Signature _____ Date _____

Because of the micropower nature of the amplifier, current levels in the driver stage (through R10, Q12, Q13, Q6) are low, varying from 0 to 3.5μa with ±3V supplies. The base currents loading the driver stage are $\frac{I_L}{\beta_{Q8} \times \beta_{Q7}}$ or $\frac{I_L}{\beta_{Q9} \beta_{Q10}}$, where I_L is the current delivered to the 1K load. If I_L is in excess of 1ma, Q7 and Q10 are clearly needed, otherwise, without them, the base currents would exceed the maximum driver current (≈3.5μa)

In addition, the μA735 does not have short circuit protection, to protect the output stage would require at least two more active devices plus two small resistors. The idling current in Q8, Q9 is determined by the diode chain Q12, Q13. Since lateral pnp's Q12A, Q13A bias vertical pnp's Q9, Q10, the biasing is rather inaccurate.

Statement of Operation _____

_____

Witnessed operation (obtain two signatures):

Signature _____ Date _____

Signature _____ Date _____

Signature _____ Date _____

Read and Understood (obtain two signatures):

Signature _____ Date _____

Signature _____ Date _____

A NEW OUTPUT STAGE FOR MICROPOWER OPERATIONAL AMPLIFIERS

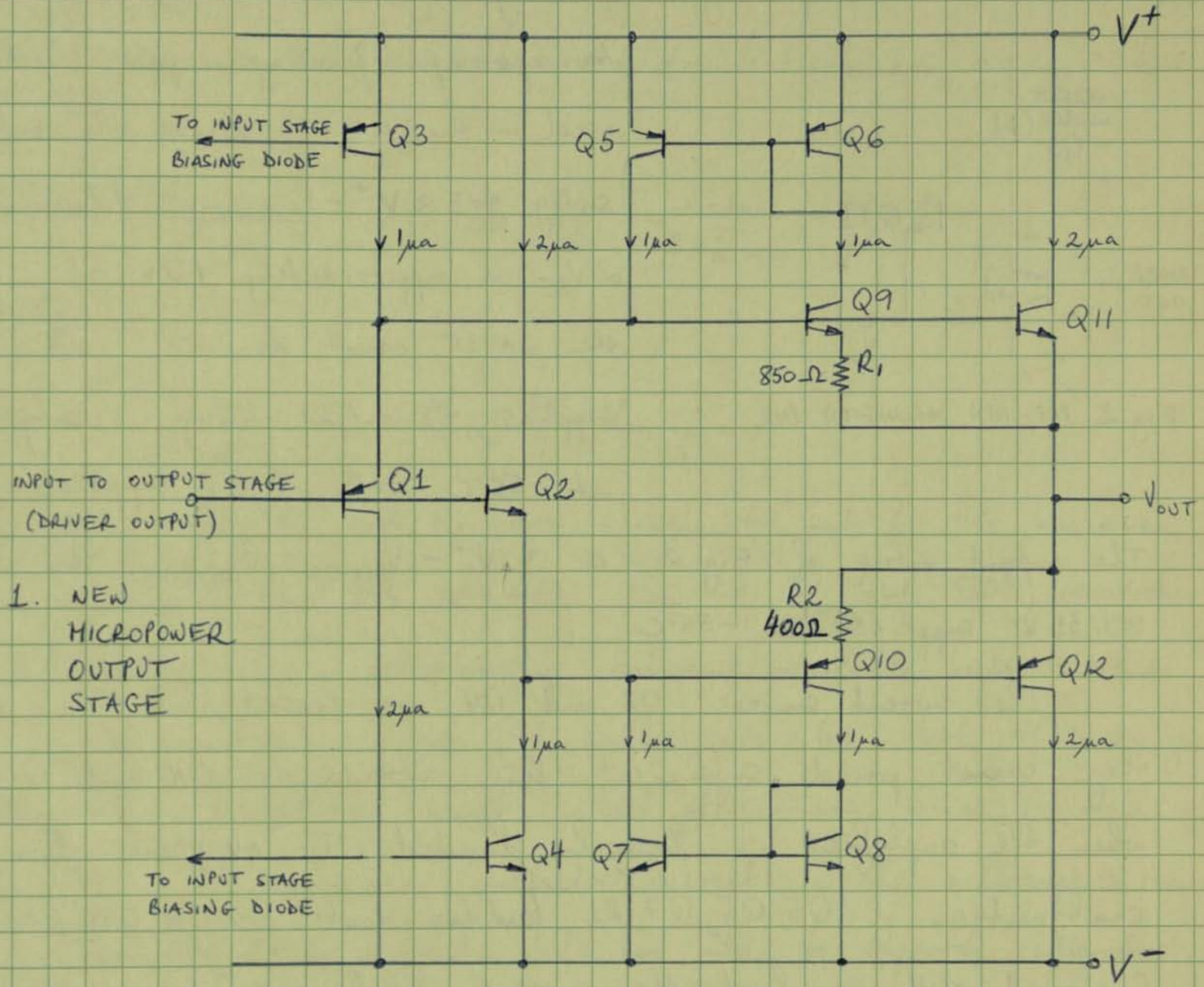


Fig. 1. NEW MICROPOWER OUTPUT STAGE

Micropower operational amplifiers should be able to deliver in excess of 1 ma to a load. Yet the current levels in the driver stage are typically one or two microamperes. Consequently, a Darlington

Statement of Operation MICROPOWER OUTPUT STAGE (BREADBOARD)

Witnessed operation (obtain two signatures):

Signature K R Stafford Date 4-11-69

Signature [illegible] Date 4-14-69

Signature George Erdi Date April 10 1969

Read and Understood (obtain two signatures):

Signature [illegible] Date 4-10-69

Signature K R Stafford Date 4-10-69

pair is needed to properly isolate the output from the driver stage.

A pnp - npn pair is used as shown in Fig. 2. (The dual of this combination for negative swings is the Q2, Q4, Q12 chain)

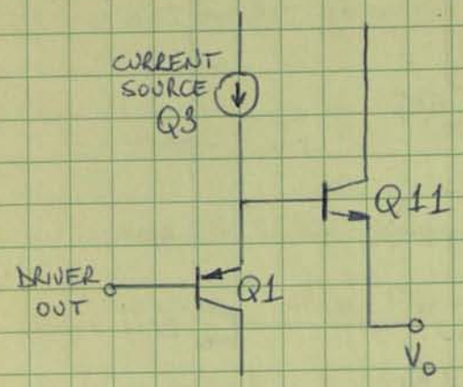


Fig. 2 PNP-NPN DARLINGTON PAIR

An npn-npn Darlington pair (such as used in the μA735) limits the output swing to $\approx V^+ - V_{saturation} - 2V_{BE}$. Since $2V_{BE}$ is approximately 1.7V at -55°C, the μA735 cannot be used with ±1.35V supplies; the output swing is only ±200 mV at -55°C with ±2V supplies.

The output swing of Fig. 2 is $\approx V^+ - V_{sat\,Q3} - V_{BE\,Q11} \approx 400$ mV with ±1.35V supplies at -55°C

The current sources Q3 and Q4 are biased at 1 μa therefore they cannot provide sufficient base currents to Q11 and Q12 when the amplifier is heavily loaded. To overcome this, the combination of Q5, Q6, Q9, R1 (and its dual Q7, Q8, Q10, R2) is employed. With no load the current levels are as indicated in Fig. 1. The voltage drops across R_1 and R_2 are negligible. The $I_{11}/I_9 \approx I_{12}/I_{10} \approx 2$ current ratios are achieved by a two to one mismatch in base-emitter junction areas between

Statement of Operation MICROPOWER OUTPUT STAGE (BREADBOARDS)

Witnessed operation (obtain two signatures):

Signature K. R. Stafford Date 4-11-69

Signature [illegible] Date 4-14-69

Signature George Erdi Date April 10 1969

Read and Understood (obtain two signatures):

Signature [illegible] Date 4-10-69

Signature K. R. Stafford Date 4-10-69

Q9, Q11 and Q10, Q12. The idling current in Q11 and Q12 is accurately established because the biasing diodes are Q1 and Q2; Q1 matching Q12; Q2 matching Q11.

The maximum available base current for Q11, $I_{B11\,max}$, at $I_{B11} >> 1\,\mu a$, is determined by

$$I_{B11\,max} = \frac{I_{C11\,max}}{\beta_{11\,min}} \approx I_{C5} \approx I_{C9} \approx \frac{kT}{qR_1} \ln \frac{I_{C11\,max}}{2I_{B11\,max}} = \frac{kT}{qR_1} \ln \frac{\beta_{11\,min}}{2} \quad \ldots\ldots (1)$$

Similarly, for Q12

$$I_{B12\,max} = \frac{I_{C12\,max}}{\beta_{12\,min}} \approx I_{C7} \approx I_{C10} \approx \frac{kT}{qR_2} \ln \frac{\beta_{12\,min}}{2} \quad \ldots\ldots (2)$$

The values for R_1 and R_2 are chosen to satisfy the maximum I_{C11} and I_{C12}, and the minimum β_{11} and β_{12} (at -55°C) requirements

The logarithmic relationship between available base current and β of equations (1) and (2) also indicates that this configuration has built-in short circuit protection. Since β falls off drastically with increasing collector current in the milliamperes range, the available base current will not able to support collector currents in excess of approximately 12 ma.

Although this output stage looks rather complex, in fact, it does not occupy more area than other micropower output stages. As a comparison, if we would add short circuit protection to the μA735, its output stage would contain 10 transistors and 3 resistors

Statement of Operation MICROPOWER OUTPUT STAGE (BREAD BOARD)

Signature George Erdi Date April 10 1969

Witnessed operation (obtain two signatures):

Signature K L Stafford Date 4-11-69

Signature [illegible] Date 4-14-69

Read and Understood (obtain two signatures):

Signature [illegible] Date 4-10-69

Signature K L Stafford Date 4-10-69

Statement of Operation_____

_____

Witnessed operation (obtain two signatures):

Signature_____ Date_____

Signature_____ Date_____

Signature_____ Date_____

Read and Understood (obtain two signatures):

Signature_____ Date_____

Signature_____ Date_____