Measuring the Pinch-Off Voltage of FET's Conveniently

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Direct measurements of a FET's pinch-off voltage cannot yield accurate values to better than ±1 volt. Consequently, manufacturers had to find a parameter interrelationship accurate enough to suffice as a replacement for this important parameter.

By definition, the pinch-off voltage has been reached when an increase in the drain-to-source voltage produces little or no increase in the drain current. As seen in Figure 1, the actual point of pinch-off lies toward the end of the knee of the voltage current curve.

Further analysis of the FET's characteristic curves has shown that the gate voltage which holds the drain current to a minimum value is approximately equal to, though opposite in polarity from, the pinch-off voltage. This is analogous to the cut-off potential in a vacuum tube. Thus with this interrelationship, it is possible to find a gate voltage which is equal in value to the pinch-off voltage. The circuit in Figure 2 shows how this gate voltage can be applied and measured conveniently, where read-out on a voltmeter connected from gate to ground gives a value which matches the FET's pinch-off voltage.

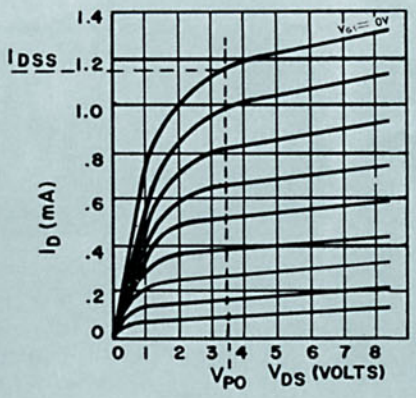

Figure 1
FET characteristic curves.

When a FET is inserted into the circuit, the drain voltage V1 approaches zero. The drain is connected to the noninverting input of the amplifier. A reference voltage V2 is connected to the inverting input of the amplifier. Since the drain is close to zero volts, the amplifier produces a negative output potential, which is applied to the gate of the FET under test, a N channel type, turning it off.

When the amplifier input voltages are balanced, there is a voltage difference V_{DD} minus V2 across the 10 MΩ drain resistor. The circuitry is designed so that voltage corresponds to the magnitude of the drain current change specified at Vpo (pinch-off voltage). In this case, with V_{DD} minus V2 equaling 1 volt, ID equals 0.1 μA.

Normally closed relay contacts are connected between the noninverting input and the output, so that the output is held to the referenced voltage (V2). A capacitor (C1) is placed across the same points to prevent latch-up by slowing the response time of the system. The devices to be measured should have a BV_{GSO} of greater than minus 15 volts. If not, the amplifier

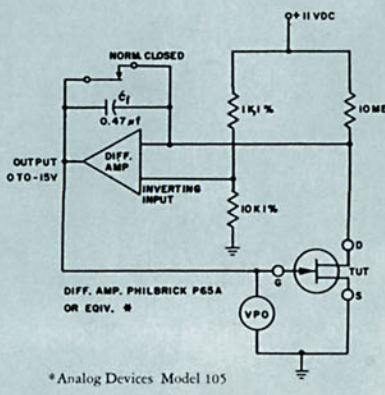

Figure 2 VPO measuring circuit.

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output should be clamped to a suitable voltage less than the minimum breakdown (as long as BV_{GSO} is greater than Vpo).

The pinch-off voltage of a P channel FET can be measured by changing the polarity of V_{DD}.

This system may be used to match FETs for differential operation (Figure 3). A match of g_m and IDSS (typically to 10 per cent) is made prior to the $\triangle$VGS measurement. The desired ID is set by the control in the gate circuit of Q1. The IR drop across Q1's drain resistor is sensed by the inverting input of the amplifier, which in turn drives Q2 until the drain voltage drops match ($ID_1 = IDS$). Because the $\triangle$VGS match is usually with 20 - 1 mV, a minimum resolution of 500 μV is required. Subsequently, to obtain this resolution the voltmeter should be of a low level differential or nulling type.

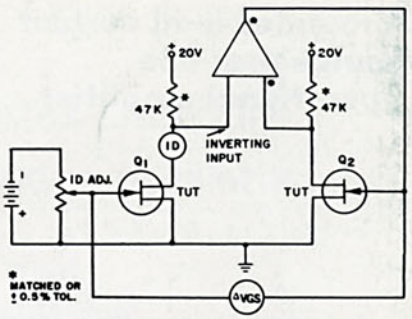

Figure 3
VGS matching for differential operation.

WORTH READING

Transconductors
Instruments & Control Systems, May, 1967
56th & Chestnut Streets • Philadelphia, Pennsylvania 19139
An excellent discussion by Erwin David, Philbrick Researchers, of transconductors showing a multitude of new applications for op amps made possible by the availability of logarithmic, quadradic, sine, cosine and arbitrary function feedback elements. Compares to digitally synthesized function generators. (6 pages)

Selecting h-f Linear D-C Amplifiers
The Electronic Engineer, April, 1967
Chilton Company
Chestnut & 56th Streets • Philadelphia, Pennsylvania 19139
A useful summary of closed loop equations for a number of common op amp configurations. (4 pages)

Linear I-Cs get larger slice of industrial control market
Product Engineering, May, 1967
McGraw Hill, Inc.
330 West 42nd Street • New York, New York 10036
An introductory article on linear I-Cs with a good comparison of specs and prices on available linear I-Cs.

Directory of IC Operational Amplifiers
Electronic Products, June, 1967
645 Stewart Avenue • Garden City, New York
Compilation of available IC op amps giving specs and prices.

Zener-Diode Function Generator
Instruments & Control System, February, 1967
56th & Chestnut Streets • Philadelphia, Pennsylvania 19139
Discusses design of non-linear transconductor using zener diode to generate arbitrary functions. (3 pages)

Working with Operational Amplifiers
Electronic Products, September, 1966
645 Stewart Avenue • Garden City, New York
Article by Carl Jackson of Nexus gives design equations and considerations for inverting and noninverting amplifier configurations. (4 pages)

Parameter Primer for Op-Amps
EDN, April, 1967
3375 South Bannock • Englewood, Colorado 80110
An article from Burr Brown which discusses the differences between the small signal and large signal frequency response of op amps, and defines such terms as slew rate, full power response and small signal bandwidth. (4 pages)

A Better Handle on Butterworth Filters
EDN, June, 1967
3375 South Bannock • Englewood, Colorado 80110
A simplified approach for deriving component values for active filters with some remarks on capacitor errors. (2 pages)

The Operational Amplifier as a Measuring Device
Electronic Instrument Digest, March, 1966
Milton S. Kiver Publications, Inc.
222 West Adams Street • Chicago, Illinois
Some interesting and useful philosophy on op amps by Daniel Sheingold of Philbrick plus a number of typical circuits for instrumentation and measurement purpose. (5 pages)

Specing IC Op-Amp Specs — Part I
EDN
3375 South Bannock • Englewood, Colorado 80110
First of a two part article, this one giving information on the significance of open loop gain specifications.

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