2x.1 What's the Actual *Leakage Current of BJTs and JFETs?*

In implementing a tricky circuit to measure extreme ranges of input currents (the "Starlight-to-Sunlight Linear Photometer," §4x.3.8), we encountered a problem that required real measurements of real transistors: the *actual* leakage current you can expect in samples of real-world BJTs and JFETs. We needed values down in the picoamps with $V_{\mathrm{BE}}=0\,\mathrm{V}$ and $V_{\mathrm{CE}}=10\,\mathrm{V}$, but the datasheets were spectacularly, uh, *unhelpful*: for example, the workhorse 2N3904 specifies no more than 50,000 pA (50 nA), and that with the base–emitter helpfully reverse-biased to $-3\,\mathrm{V}$, but with $V_{\mathrm{CE}}=30\,\mathrm{V}$. The situation with JFETs was not better: for our MMBF5460 the brave manufacturers were willing to specify only a gate leakage current of 5,000 pA (5 nA), and they offered no usable limits on the off-state channel current.[2].

So, we took the challenge: we warmed up our Keithley 6514 "Programmable[3] Electrometer," and set out to measure what these puppies actually do. The results are comforting: for small-signal BJTs (2N3904/06 200 mA-class) you can expect room-temperature zero-bias leakage currents to be at most 1 nA, and often one to three orders of magnitude less (Fig. 2x.1). The measurements plotted in that figure include some 20 different '3904 samples, including parts from 11 manufacturers spread over 17 different date codes. Compared with BJTs, the small JFETs fare considerably better (Fig. 2x.2), with leakage currents rarely more than 1 pA (spread only over one order of magnitude, and correlated roughly with current rating).

This was good news for our Chapter 4x photometer. But we offer a *caution*: you cannot depend on unspecified parameters. Even though you may suspect that the manufacturers are low-balling the capabilities of their offerings (or just being lazy in their testing), you should be not unprepared for an unpleasant surprise, someday. So, if you want to exploit components beyond their official specifications, you must be willing to perform tests on incoming parts, to ensure they do what you need them to do. Don't forget, also, that leakage currents rise exponentially with temperature, typically doubling for every 10°C increase in temperature.

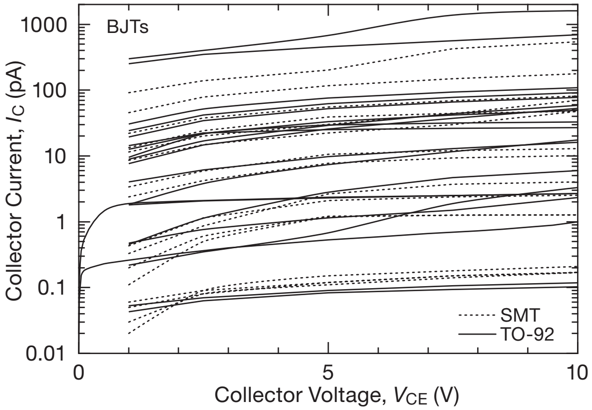

Figure 2x.1. Collector leakage current for a selection of small-signal transistors (2N3904, 2N3906, 2N4401, MPSA42, and SMT equivalents), measured at room temperature with $V_{\mathrm{BE}}=0$.

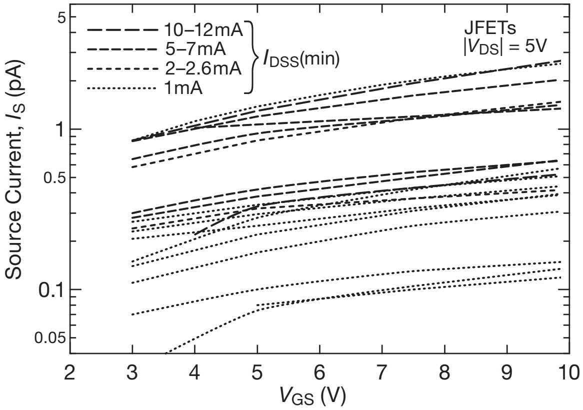

Figure 2x.2. Channel (source-terminal) current versus gate–source voltage for a selection of JFETs (2N5457, 2N5460, and SMT equivalents; and J309, J175, 2SJ74BL, LSK170B, LSK389B, BF861A, BF861B, BF862, and PMBF4395), measured at room temperature with $V_{\mathrm{DS}}=5\,\mathrm{V}$.

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[2] For which the only information was the threshold drain current that defined "cutoff," namely 1,000,000 pA (1 μA)

[3] But, consistent with our old-school instincts, we ran it manually. Takes too long to learn the magic commands.