This paper demonstrates the first-of-its-kind additively manufactured microfluidics-based flexible RF sensor, combining microfluidics, inkjet-printing technology, and soft lithography, which could potentially enable the first “real-world” wearable “smart skin” applications. A low-cost, rapid, low-temperature, and zero-waste fabrication process is introduced, which can be used to realize complex microfluidic channel networks with virtually any type of sensing element embedded. For proof-of-concept purposes, a reusable and flexible microfluidics sensor was prototyped using this process, which only requires 0.6-µL fluid volume to produce a 44% frequency shift between an empty ($\epsilon_r = 1$) and a water-filled channel ($\epsilon_r = 73$), demonstrating a sensitivity that is higher than most previously reported microfluidics-based microwave sensors. Seven different fluids were used to measure the sensitivity of the prototype and an overall sensitivity of 24% / log (ϵ_r) was observed. The “peel-and-replace” capability of the presented sensor not only facilitates the cleaning process for sensor reusability, but it also enables sensitivity tunability. For bent/conformed configurations, the sensor's functionality is good even for a bending radius down to 7 mm, demonstrating its great flexibility. After bending multiple times, the sensor still exhibits a very good performance repeatability, which verifies its reusability feature. The introduced additively manufactured RF microfluidics-based sensor would be well suited for numerous wearable and conformal fluid sensing applications (e.g., bodily fluids analyzing and food monitoring), while it could also be utilized in a variety of microfluidics-reconfigurable microwave components.